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JOINERY
STAIR BUILDING
IRONMONGERY
PLASTERING
GLASS AND GLAZING
PAINTING AND DECORATING
ELECTRIC WIRING AND BELLS

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JOINERY

(PART 1)

JOINTS AND DOOR CONSTRUCTION

JOINTS

EXPANSION AND CONTRACTION

1. Province of Joinery.—**Joinery,** as distinguished from *carpentry,* is that branch of the woodworking trades which deals with those interior and exterior fittings of a house that are put in place after the rough framework and flooring are finished. Among such fittings may be mentioned the floors, skirtings, casings, wainscotings, doors, windows, panelled partitions, and staircases. In joinery, the chief objectives are close-fitting joints, accurate workmanship, and smooth-finished surfaces; whereas, in carpentry, the main object is to provide a frame, or skeleton, strong enough to resist any stress to which the building may be subjected, and yet so arranged as to comply with the requirements of the finished joinery.

Thus it happens that, while the carpenter deals principally with heavy timbers in the rough, the joiner uses smaller pieces of finer and more carefully seasoned woods, and joins and fits them with the utmost accuracy. The joiner, therefore, must work with much more care and to a higher degree of finish than the carpenter. All the surfaces which the joiner leaves exposed must be smooth and clean, ready for the painter, varnisher, or polisher.

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2. The joiner's time is divided between the duties of the workshop and the building. In the workshop, he prepares the framed and panelled work, door frames and casings, window frames and sashes, all classes of moulded work, and the various parts required for staircases, interior fittings, and general finish. In the building, he attaches the finished woodwork to the framed base, consisting of false jambs, furring strips,* and grounds, all of which he should verify as to correct levelling, plumbing, and alinement before he applies the materials. These, in due course, should have been placed correctly by the carpenter, but a careful joiner will always make an examination of existing conditions, so that he may meet them with larger intelligence.

3. Provision for Expansion and Contraction.—All wood is subject to a change in width across the grain ; all joinery work, therefore, that is not framed, or built up, should be so fixed that it is free to expand and contract. In a broad surface, such as a plain wainscot, this is accomplished by securing one edge only and permitting the other to rest in a groove, but in such a position that it may contract as the wood shrinks, or expand when affected by dampness. When both edges are secured, shrinkage will cause the wood to split, and when dampness causes it to swell, it will either bulge in the middle or push out the securing nails or screws.

It may here be noted that a thorough knowledge of the properties of various woods is even more important in joinery than in carpentry. The slightest tendency of the material to warp, shrink, or swell must either be counteracted or prevented ; for, however well seasoned the wood may be, it will always shrink somewhat across the grain when exposed to the warm dry atmosphere of a dwelling house, and, unless properly secured, thin panels will surely warp. For this reason, narrow boards are always preferable to wide ones, as the shrinking is distributed over a larger number of joints and is less noticeable ; and, if the narrow strips are properly placed with respect to their original position in the tree, the tendency to warp may be largely overcome.

* In Scotland, furring strips are sometimes called *wall straps*.

CLASSIFICATION OF JOINTS

4. To ensure durable and flush connections between the parts joined together, due consideration should be given to the form and character of the joints, so that the stresses to which they are subjected may be either resisted or compensated. The stresses may be caused either by the behaviour of the material itself or by extraneous force in the working portions, as doors, shutters, and window sashes.

In *Carpentry*, Part 2, a number of joints commonly used in house building are described in detail. Although many of these joints are identical in principle with those used in joinery, there is a vast difference in the degree of accuracy required in the workmanship. In joinery, the joints may be divided into two classes; namely, *loose joints* and *glued joints*. Loose joints consist of two or more pieces held in place, primarily, by the shape of the parts of union, although glued when put together for interior work, such as the dovetail joint, Figs. 8 to 11. Pieces of the second class, however, are secured by means of glue, as in the mitre joint, Fig. 2; the shouldered corner, Fig. 3, etc.

5. Loose joints are seldom used in joinery, except in heavy machine frames and in pieces of cabinetwork which are made in sections for convenience in handling, or in the exterior finish of a building where exposure to the weather would render the glued joint unreliable. In any case, the loose joint is usually rendered additionally secure by means of screws, nails, or wooden pins.

6. Glued joints require some mechanical contrivance to hold the parts in position while the glue is setting. This setting usually occupies from 12 to 48 hours, according to the quality of the glue, the condition of the atmosphere, and the temperature of the room. Considerable experience is required in order to use glue successfully. The wood must be well seasoned and thoroughly dry, and the joint must be well fitted. In the case of hardwoods, the surfaces to be glued should be roughened with a toothed comb, to make the glue hold better, the room

must be at a proper temperature, and the material must be heated, so that the glue will flow quite freely. The glue should be spread evenly and thinly on the parts, which are then placed together as soon as possible and held in place by means of hand screws, bench clamps, or wedged frames. All superfluous glue is wiped off and the work allowed to stand until the joint is thoroughly dry.

The most frequent causes of bad gluing are the use of inferior glue and the unequal spreading of it. A good practical test of any brand of glue is to glue together a piece of pine and a piece of ash, clamp them with a hand screw, and when they are dry insert a chisel in the joint and endeavour to force them apart. If the joint separates where it is glued, the adhesion is inferior, and the glue should not be used for good work. The wood should split, or give way, rather than the material which secures the joint.

7. Butt Joints.—The simplest joint used in joinery is the **butt joint,** shown in Fig. 1. Here, the two pieces are simply

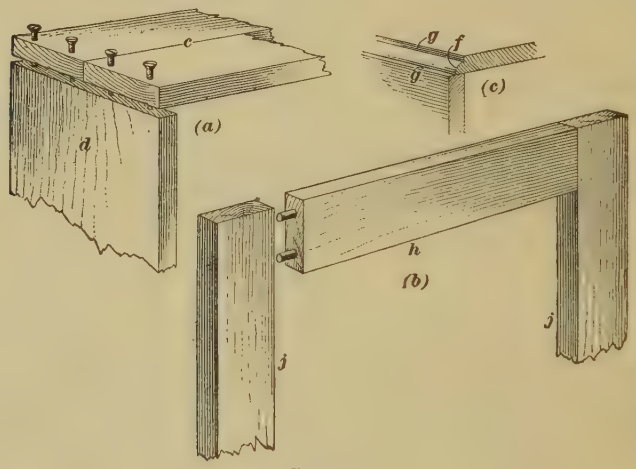

FIG. 1

butted together as in the butt joint in carpentry. The adjacent surfaces, however, are much more accurately fitted and are held in place by means of screws or dowels, the former when the

pieces are broad and thin, as in Fig. 1 (*a*), and the latter when the timbers are heavy and thick, or when they are to be joined together on the thinner edges, as in Fig. 1 (*b*). This simple form of joint is insecure and usually requires glue to make it reliable; it may also be kept in place by the woodwork against which it is erected, as would be the case in an exterior casing for a window. If the form shown in (*b*) is used, the top *h* should rest on the sides *j*.

The plain butt joint, shown in Fig. 1 (*a*), is seldom used in first-class joinery work, as the opening caused by shrinkage is very apparent. The absence of a device to keep the entire surface flush allows the fibres to curl, and the effect of shrinkage and warping would be to cause the pieces *c* to project slightly over the side of *d* and render the juncture too apparent. This may be obviated, to a certain extent, when the grain runs parallel with the joint, by forming the joint as in (*c*); a quarter round *f* is worked on one of the pieces to be joined, thus forming fillets, as shown at *g g*. The joint shown in (*a*) may also be dowelled, as in (*b*).

8. **Mitre Joint.**—The **mitre joint,** shown in Fig. 2, is generally used when the boards are of the same thickness, where no great strength is necessary, and where the conditions require that the angle shall show no end grain of the wood, either inside or outside the joint. This joint is usually nailed or screwed together as shown, but depends on glue to make it secure, or is strengthened by a **slipfeather,** or **spline,** as shown dotted at *a*. It is also sometimes secured by gluing in a key of thin wood, which is inserted in a saw kerf cut diagonally, as at *b*, or at right angles to the end, as at *c*. A **keyed mitre** is generally used for a joint seen only from the interior, as the keys

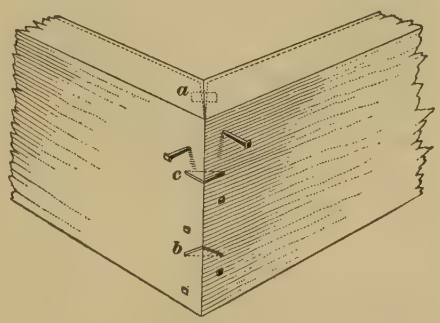

Fig. 2

disfigure the exterior. This joint is also made with the broad portion of the wood on the face, as in the case of architraves and casings. In mitred joints, the shrinkage of the wood does not change the appearance of the exterior of the joint, but causes the interior to open slightly, as indicated by the dotted lines. To obviate warping, however, a tongue is very essential.

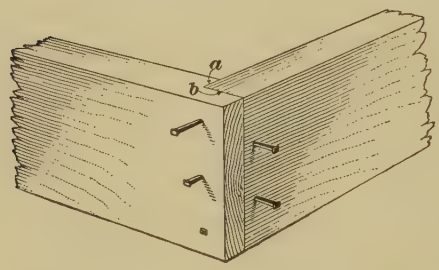

FIG. 3

9. Shouldered Corner. The **shouldered corner,** shown in Fig. 3, is a joint used where the inside angle alone will be visible, and is an improvement on the butt joint shown in Fig. 1 (*a*), inasmuch as it provides two nailing surfaces, one at *a* and one at *b*.

10. Shouldered-and-Mitred Joint. — The **shouldered-and-mitred joint,** shown in Fig. 4, is a combination of the forms shown in Figs. 2 and 3. This joint has the advantage of showing no end grain, as does Fig. 3, and possesses the additional strength secured in the method of joining the pieces illustrated in the same figure. The use of this joint, however, is limited to light work, where great strength is not needed, being especially serviceable where a mitre joint is required between pieces of unequal thickness, as in Fig. 4.

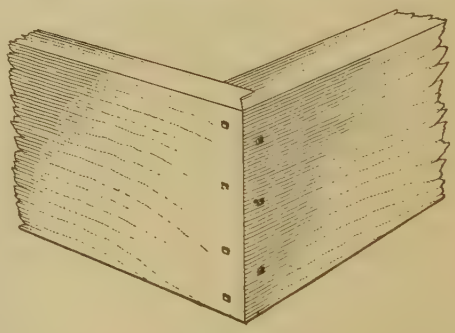
FIG. 4

11. Tongued-and-Grooved Joints.—The **tongued-and-grooved joint,** Fig. 5, the **housed-and-shouldered joint,** Fig. 6, and the **housed joint,** Fig. 7, are all modifications of the same form, where

the end of one piece is let into the side of another piece about one-third of its entire thickness. These joints are very frequently used in joinery. They are secured by means of glue, nails, or

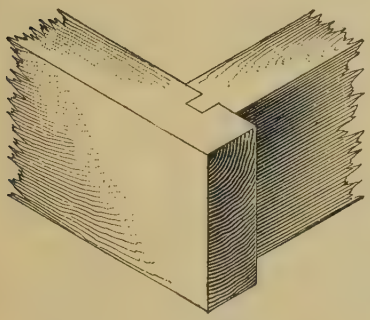

Fig. 5

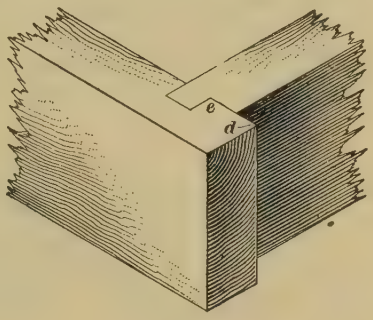

Fig. 6

screws, or may be left loose to allow the parts joined to adjust themselves during shrinking and swelling.

In joining the back and sides of a drawer, the forms shown in Figs. 6 and 7 are frequently used, as the projection of the sides of the drawer, as from *e* to *d*, renders the end less likely to be pulled off by the jar of the contents when the drawer is suddenly opened; and any unequal shrinkage of the two pieces will not tend to split the material, provided the joint is not secured by too many nails.

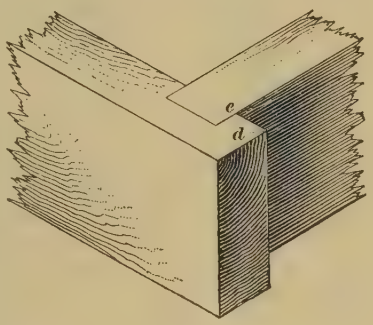

Fig. 7

12. Dovetail Joint.—The **dovetail joint** is one of the most important in joinery; it furnishes a rigid method of securing pieces together where the fibres of the material are approximately at right angles to the joint. Its strength depends on the combined value of the dovetails just as a nailed joint depends on the combined resistance of the nails, or as a nut on a bolt depends on the aggregate strength of the threads for its holding power. The extent to

which this is true is shown in Fig. 8 (*b*). The projections on the piece *b* are liable to fail by the shearing of the flare, or dovetail, on each side of the projection, the strength in this case depending on the capabilities of the wood to resist shear across the grain; while the projections on the piece *d* depend for their strength on the resistance of the flares, or dovetails, to the shear of the wood parallel with the grain.

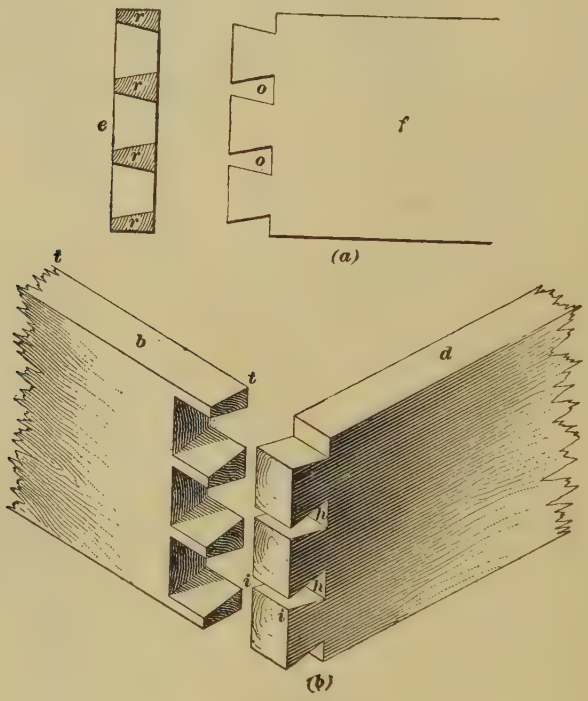

Fig. 8

The projections on the pieces *d* and *b* are also liable to fail by shearing through, or by breaking off where they join the main pieces of wood; consequently, the distance from *h* to *h* and the corresponding distance on the projections on the piece *b* should never be so slight as to be liable to break before the shearing strength of the wood across, or parallel with, the grain is realized. Another factor entering into the strength of a

dovetail joint is the adhesive strength of the glue which binds the fibres of the projections on the pieces united, giving rigidity to the joint and preventing the piece *d* from pulling away from *b* in a direction parallel with the grain of the latter.

13. Dovetail joints are of three kinds. The **common, or lap, dovetail** has its dovetails on *d*, Fig. 8 (*b*), and its dovetail pins

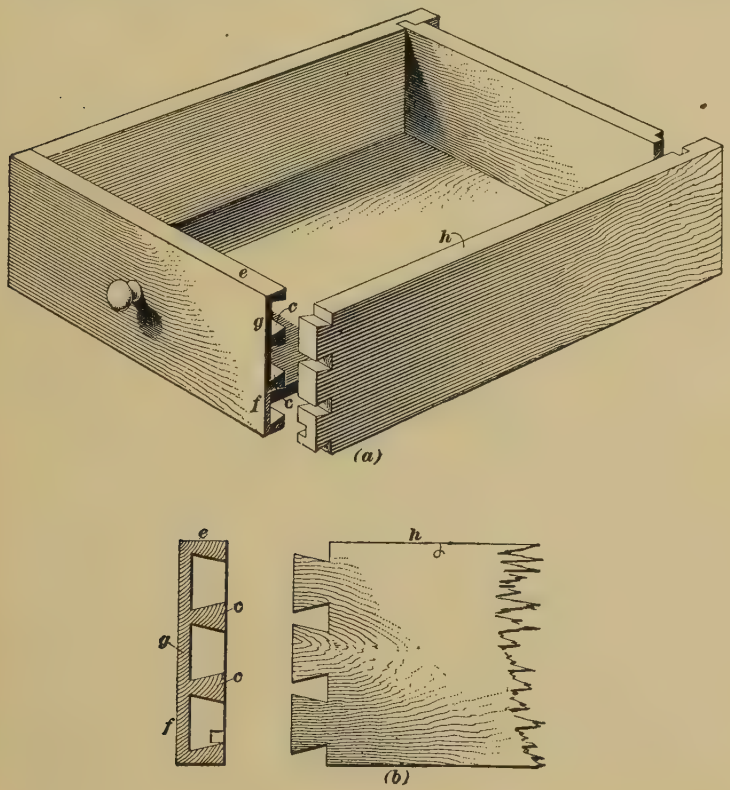

FIG. 9

project from the body of the piece *b* a distance equal to the thickness of the piece *d*. The ends of the pins and dovetails show on opposite sides of the corner when the pieces are joined. In preparing the joint, the pins *r*, Fig. 8 (*a*), are marked and cut first; the piece *e* is then laid across the end *f*, and the

mortises *o* are carefully marked with a knife point on the side of the end of *f*. The pins must be sawn at right angles to the end, or parallel with the edge *t t*, Fig. 8 (*b*), and the mortises must be cut square across the end of piece *d*, as at *i i*, the greatest neatness and accuracy being required to ensure good work.

14. The **half-lap dovetail** is shown in Fig. 9 (*a*) and (*b*). The pins *c*, though cut down from the end of the board *e* a distance equal to the thickness of the board *h*, are not cut entirely through the board *e*, but have, as at *f*, *g*, a lap covering the ends of the dovetails on *h* when the joint is closed. This entirely

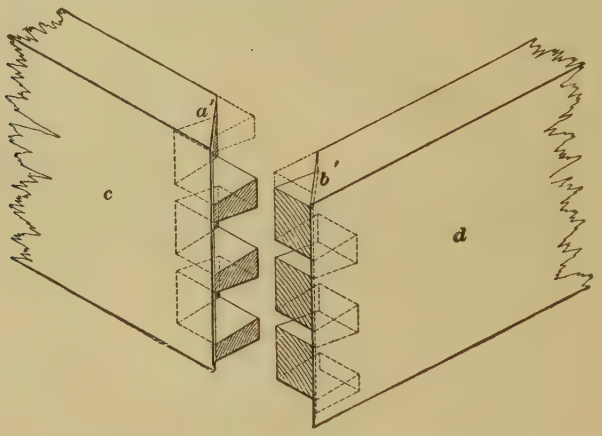

FIG. 10

prevents the character of the joint from appearing on the face of *e*, although the end grain of the pins *c* will show through the board *h*. This joint is well adapted for the fronts of drawers, as shown in (*a*), as the piece *e* which shows no dovetails forms the front of the drawer, and the ends of the dovetail pins on the side piece *h* are hidden when the drawer is closed. The side elevation of the joint and the relative size of the dovetails and dovetail pins are shown in (*b*). The reference letters refer to the same details in both (*a*) and (*b*).

15. The **blind, or secret, dovetail** is shown in Fig. 10. In this joint about three-fourths of the thickness of the board is dovetailed and the remaining portion is mitred. Both the dovetails

and the dovetail pins are here cut only partly through the board. The upper pin a' of piece c is cut off on the mitre line of the angle, while the upper half of mortise b' is cut only to the mitre line of the piece d, thereby concealing entirely the details of the true character of the joint when the pieces are united. This joint is seldom used, except for the front corners of highly finished drawers and boxes, where, for the sake of appearance, it is judged to be better that the dovetails should not show. The blind dovetail is not so strong as either of the other forms, partly because it utilizes only a portion of the available thickness of the wood, and partly because, on account of their concealment, it is impossible to see whether the pins and mortises fit accurately.

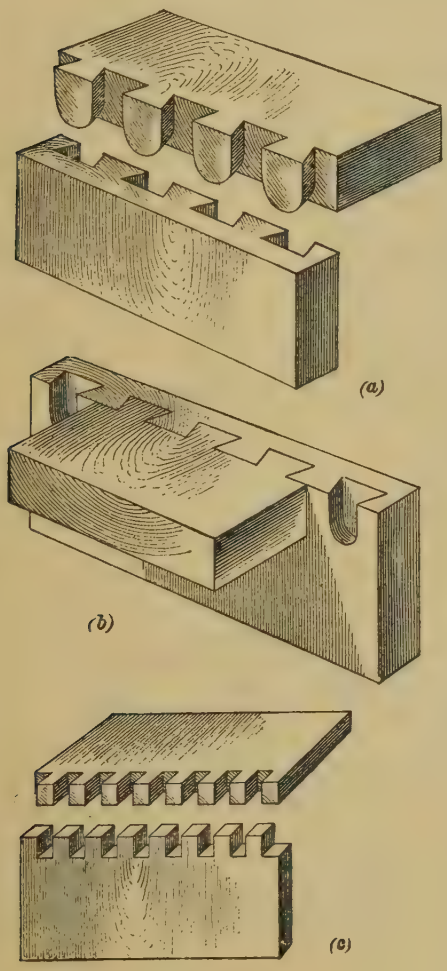

FIG. 11

16. Machine Dovetailing.—Fig. 11 shows two forms of dovetailing that are executed by machinery. The form shown at (*a*) and (*b*) is used for the same purposes as that shown in Fig. 9, namely, for drawers, cabinets, etc., while that shown at (*c*) is used principally in making small boxes and filing cases, etc., and may be used with or without glue.

17. Dowelled Joints.—The **dowelled joint**, shown in Fig. 12, consists of a plain butt joint between the two pieces *e* and *f*, either between one end and a side, as in (*a*), or between the two meeting edges, as in (*b*). Holes are bored, and dowels are glued and inserted as shown. The object of the dowels is to keep the faces flush, and to render the joint stiffer if subjected to a transverse stress. The holes should be somewhat deeper than the length of the dowels, to allow for shrinkage of the material

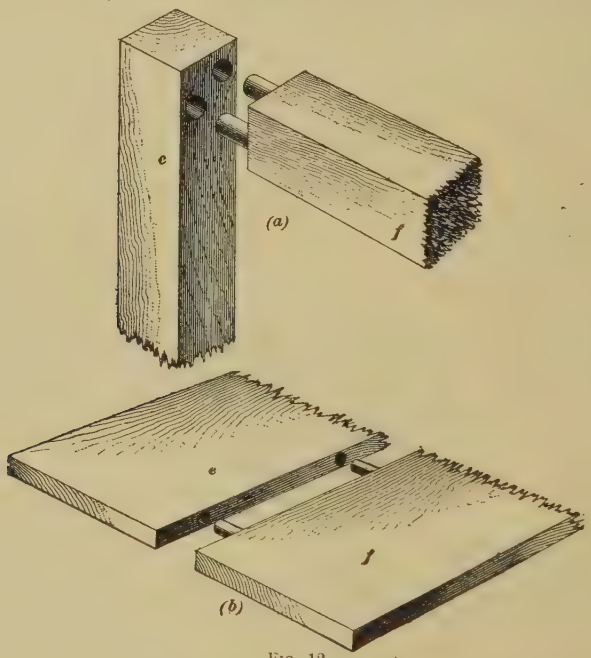

FIG. 12

and at the same time ensure a close joint. The form shown in (*a*) is often used as a substitute for a mortise-and-tenon joint, but is not to be recommended.

18. Mortise-and-Tenon Joint.—The **mortise-and-tenon joint** as used in joinery is precisely identical in principle with the same joint in carpentry, but the fitting is much more accurate. This joint, in varied forms, is used to secure the rails and stiles

of doors and windows, to unite the members of heavy machine frames, and to connect the various parts of tables, chairs, and other pieces of furniture.

19. Keys and Keying.—When broad, plain surfaces, such as dados, window backs, table tops, etc., are required, the boards forming them are generally tongued and grooved together or are dowelled and united with glue; but, to secure the surface against warping or twisting, pieces of wood called **keys** are let into a dovetailed groove in the back, as shown at *a*, Fig. 13. These keys are either planed off flush with the surface into which they are sunk, or, when extra strength is required, they may stand up from the back, as shown at *b*. Keys should not be glued in position, but are sometimes secured with a single screw or nail at one end, as shown at *c*, so that when the material shrinks it will slide on the key, and the joint along the keyway, or groove, will still remain tight.

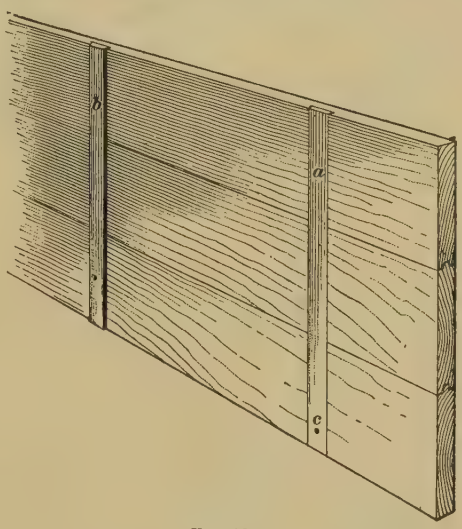

FIG. 13

20. Clamping.—Boards are sometimes kept from warping by means of **clamping,** as shown in Fig. 14. The boards *a*, *b* are dowelled or tongued and grooved together on their interior edges to form a close joint, as at *c d*, and the clamps *h*, *j* are glued over tongues worked on the ends of the boards, as shown at *e*. In first-class work, tenons *f* are also worked on the boards *a*, *b*, and, by insertion in the mortises in the clamp *h*, strengthen the joint materially. When it is undesirable to show the end grain of the clamp, as at *e*, or of the tenons, as at *f*, the ends

of the clamps are mitred off, as shown at *g*, and the tenons do not extend entirely through the clamp.

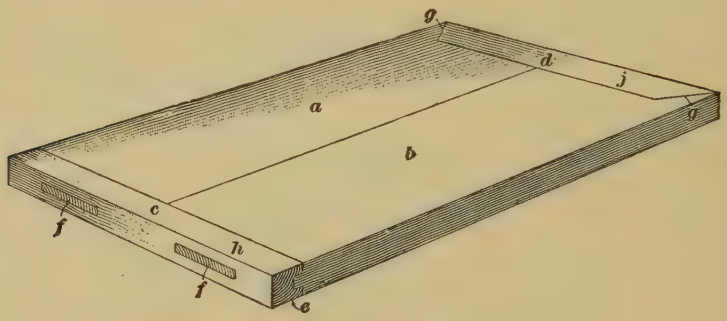

Fig. 14

Tenons and mitred clamps can only be satisfactorily used when the material is thoroughly seasoned and where the finished product will not be subjected to changes in temperature, as these connections furnish no provision for expansion and contraction.

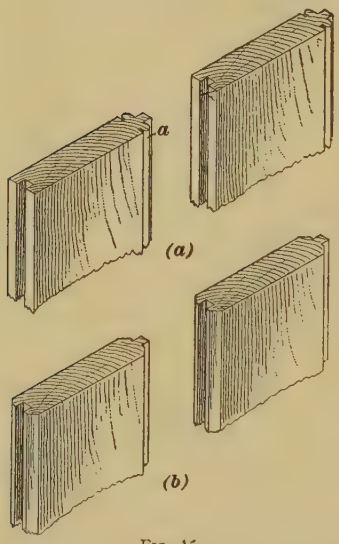

Fig. 15

21. Matching.—A joint greatly used on the edges of boarding, and in similar positions, where it is necessary to prevent an open joint in case of shrinkage, is the **matched joint** illustrated in Fig. 15. That shown in (*a*) is known as a *matched-and-beaded joint*, and that in (*b*) as a *matched-and-***V***-jointed joint*. The beading *a*, to a great extent, hides any opening of the joint between the two boards due to shrinkage. Matched boarding is often used for covering the surface of wooden partitions in positions where the use of plastering is not desired. These boards should be nailed only on

one edge, the other being secured by the tongue and groove of the joint, so that the board is free to move in shrinking.

22. Marking Joinery Work.—In all joinery work, face and edge marks are made so as to distinguish the face and the edge, and from these marks all measurements must be taken and all squaring done. At the same time, these marks serve to assist the joiner in determining the edges that are to be in contact, and prevent mistakes due to improperly putting the pieces together.

SPECIAL OPERATIONS

SPLAYED WORK

23. Splayed work is the term applied in joinery to cases in which some of the surfaces slope, or slant, from or toward other surfaces, such as the sides of a pyramid. Such work is frequently encountered in the jambs, sills, or sides of windows or doors, or in the sides of any piece of work placed in an oblique direction to a horizontal or vertical plane.

The sides of the box in Fig. 16 *splay* out equally from the bottom *a b c* to the top *d e f*. The angles required in the construction of such a square box, or hopper, may be found as follows: Let *b c*, Fig. 17, be the required splay and position of the sides of a box in relation to the horizontal plane *s d*, and *a b* the thickness of the material from which the box is to be made; then, *a b c t* and *x z s y* are cross-sections of the sides of the box. From *c*, at right angles to *s d*, draw *c j* equal to *c b*; through *j* parallel with *s d* draw *p h*, and from *b* draw *b h* at right angles to *p h*; connect *h c*; then, the angle *j h c* is the inside face

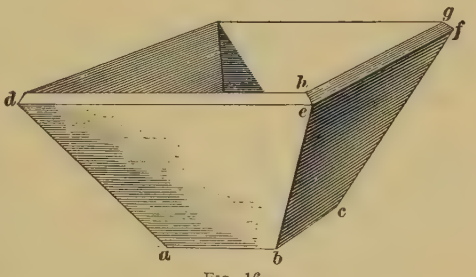

FIG. 16

bevel for the sides, and *p h c s* is the size and shape of the inside faces.

24. To find the bevel for a butt joint on the square edge, in Fig. 17, from *a* draw *a f* parallel with *h j*; from *f*, draw *f g* at right angles to *h j*; make *i g* equal to the thickness *b a*, and connect *h g*; then, *j h g* is the bevel. To find the bevel for a

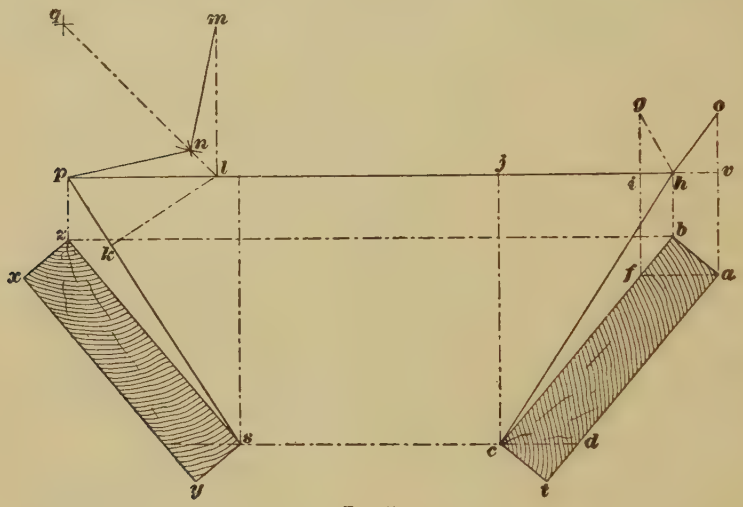

Fig. 17

mitre joint on the square edge, as *g h e* in Fig. 16, draw *a o*, Fig. 17, at right angles to *f a*, making *v o* equal to *b a*; connect *h o*; then, *j h o* is the mitre bevel.

25. To find the angle between the two inside faces in a plane at right angles to the face joint *p s*, draw *k l* at any point along the line *p s* and at right angles to it. At right angles to *p l*, draw a line from *l*, and make *l m* equal to *l p*. With *m* and *p* as centres, describe the intersecting arcs at *q*, and connect *q l*; with *l k* as radius and *m* and *p* as centres, describe intersecting arcs at *n*; connect *n* to *m* and to *p*; then, *m n p* is the angle sought. Also, the angle *p n l* is the angle of mitre through the thickness, holding the stock of the bevel in the direction *k l*. A block bevelled to the angle *m n p* will fit the angle formed by the

connecting faces of the box. If either edge of the box is cut off horizontally, as at *c d* or *f a*, a square line on either of these edges from the face *c b* will be a butt-joint line through the thickness. An angle of 45° applied from the outside face on either bevelled edge *c d* or *f a* will be a correct mitre through the thickness. In dovetailing a box like this, instead of squaring across the ends for mortises, use the angle *c f a* or *d a f*; also, instead of squaring from the ends for the pins, use the angle *c h j*.

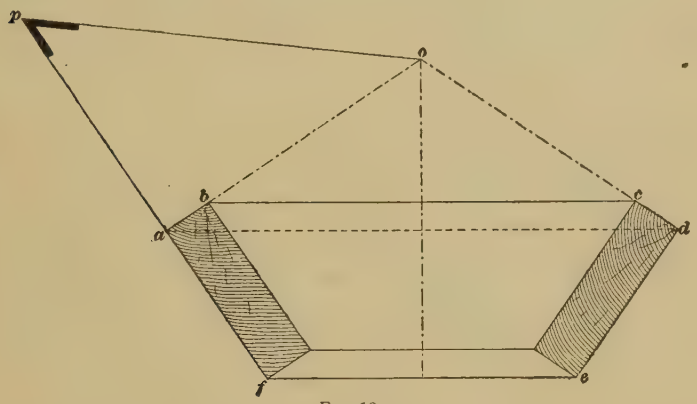

Fig. 18

26. A simple method of finding the mitre joint on the square edge is shown in Fig. 18. The mitre joint is the same as the lower face joint of a pyramid formed by the continuation of

Fig. 19

the edges *a b* and *d c* until they intersect at the centre *o*. Let *a b c d e f* be a vertical section through the centre of the box. Set off *a p* perpendicular to *a o* and equal to half the length of

the outside edge $a\,d$; connect $p\,o$; then, $a\,p\,o$ is the required mitre bevel to be applied from the outside face. The application of the mitre bevel from the inside edge is shown in Fig. 19 (*a*), and the bevel for the butt joint in Fig. 19 (*b*).

CURVED MITRES

27. To mitre a straight and circular moulding, the straight moulding to be tangent to the circular one, let $o\,o'\,t\,t'$, Fig. 20, be the circular moulding, and x a cross-section of it; let $s\,s'\,r'\,r$

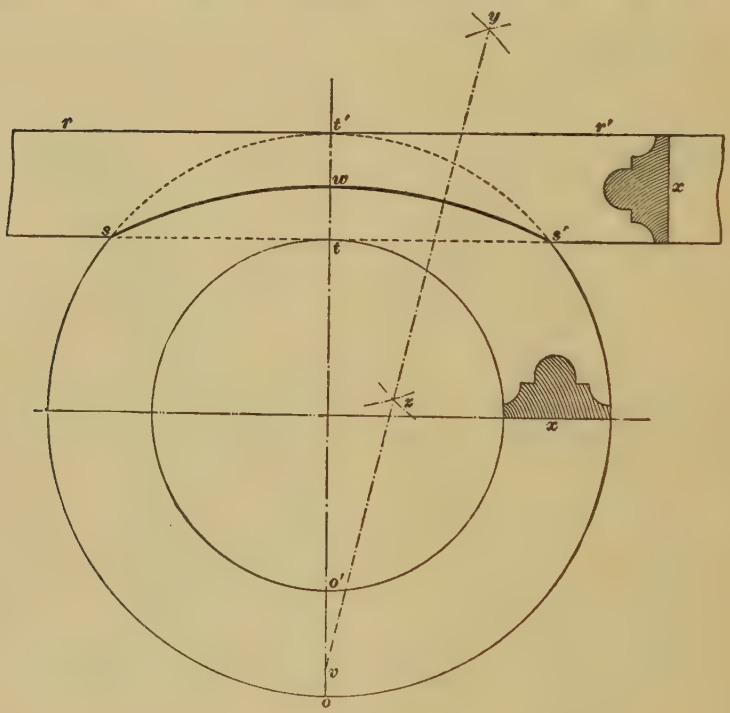

Fig. 20

be a straight moulding, with a similar cross-section x. Bisect $t\,t'$ at w; with s' and w as centres and equal radii, describe intersecting arcs at y and z; join y and z, and produce the line

to intersect $o\,t'$ in v. Now, from v as a centre, describe the arc $s\,w\,s'$, which will be the mitre line required.

28. To mitre a straight and circular moulding intersecting at an acute angle, let $b\,a'\,a\,c$, Fig. 21, be the straight moulding and $a\,a'$ the cross-section; $z\,z'\,c\,b$ the circular moulding and $z\,z'$ its cross-section. Through both mouldings draw the centre lines $t\,s$ and $o\,s$, respectively. With c and s as centres and a radius greater than the distance $c\,s$, describe intersecting arcs,

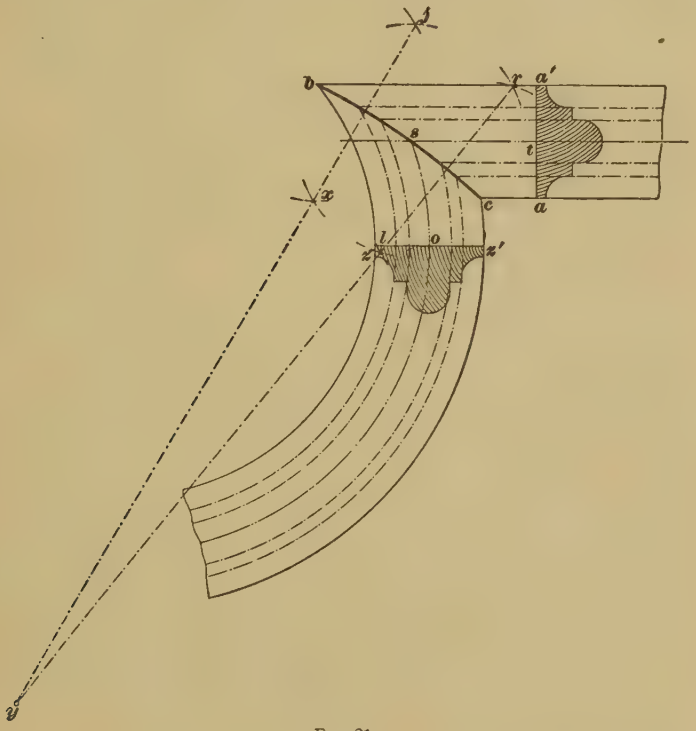

Fig. 21

as r and l, and through r and l draw the line $r\,y$ of indefinite length. With s and b as centres and a convenient radius, describe intersecting arcs as j and x, and through these points draw the line $j\,y$, cutting the line $r\,l$ in the point y. With y as a centre, describe the curve $b\,s\,c$, which will be the mitre line required.

RAKING MOULDINGS

29. The following is a method of finding the profiles of gable mouldings to mitre accurately with eave mouldings: A profile of the eave moulding is shown at *a b f h j c e*, Fig. 22. Let *m d c'* be the pitch angle of the gable moulding. To find the profile of a moulding that, with the given pitch, will mitre accurately with *a b j c e*, proceed as follows: Divide *b j c* into any number of parts, as at *f, h, j*, etc. Through the points of division draw verticals, as *f f'*, etc., and draw *l k* parallel with *d m*. Draw *f g*, etc., parallel with *d c'*, and at any point set off *k' f'' l'* equal to *k f' l*. Draw *l' b'*, etc., at right angles to the pitch of the gable, cutting *b b''*, *h i*, etc., in the points *b'*, *h'*, etc., which will give points in the required profile.

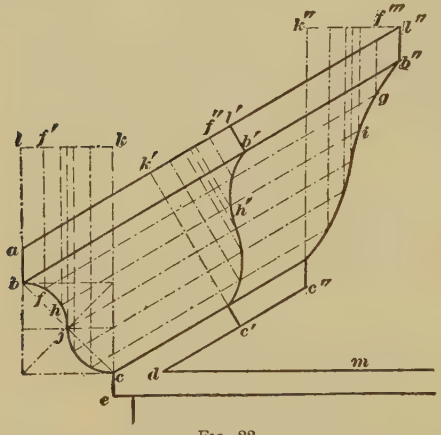

FIG. 22

To find a vertical section of the raking moulding, for use in profiling return mouldings, at broken pediments, proceed as shown at *b'' c''*. Draw *k'' l''*, with its divisions equal to and parallel with *k l*. Drop verticals from the points of division as before, intersecting the lines *b b''*, *f g*, etc., in the points *b''*, *g*, *i*, *c''*, etc. By drawing a curve through the points thus found, a vertical section of the return moulding is obtained.

BENDING WOOD

30. When a surface must present a curved form, the wood may be bent round it by any one of five methods, namely: by *saw kerfing*, *keying*, *backing a veneer*, *laminating*, or *steaming*.

31. Saw Kerfing.—As saw kerfing is less costly than other methods, it is often adopted. The method is not to be recommended, however; it makes a weak construction, and no matter how perfectly the work may be done or how well it may be painted, the saw-kerf marks will always show. For hardwood mouldings, the method should never even be considered, and for curved work of any kind, solid moulding should always be used.

A centre built to the desired diameter, or curve, over which the material may be bent, and which will stay permanently and accurately in its curved form, is absolutely necessary with any

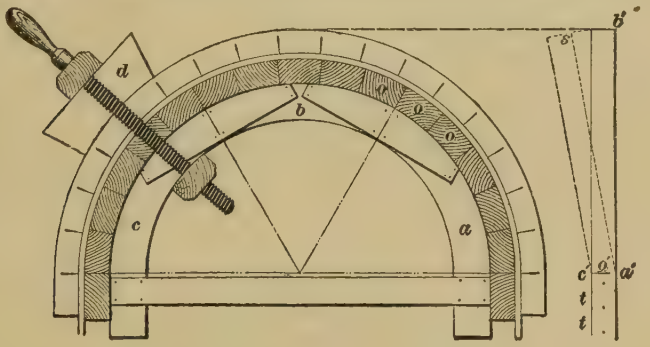

Fig. 23

of the methods just mentioned. In Fig. 23, the rib *a b c* used for a centre is composed of three pieces of $1\frac{1}{4}$-inch plank. This rib is made concave on its inner edge, merely because it is sometimes an advantage, when it can be done, to clutch the bent material and the rib with handscrews, as shown. Blocks, as shown at *d*, extend the power of handscrews considerably beyond the width of the jaws, and are therefore exceedingly useful. The staves of wood *o*, of any length required, are nailed to the rib *a b c*, and form the circular surface of the centre.

32. To find the distance between saw kerfs that will allow the material to bend to the curve required, take a piece of suitable length and equal to the thickness of that which is to be bent, as at *c' a'*, and let *a' b'* be equal to the radius of the curve to which it is to be bent. Make a saw kerf at *c' o'*, leaving uncut a thickness *o' a'* from $\frac{1}{4}$ to $\frac{1}{8}$ inch; nail the piece at *t*, *t*, and move

it from b' to s, or enough to just close the saw kerf at c'; then, $b's$ will be the given distance between two saw kerfs. The distance $a'o'$ to be uncut must be gauged along each edge of the piece to be bent, and the same saw must be used with which the cut $c'o'$ was made. In this method of bending, a thin veneer is first laid, and the saw-kerfed piece is then bent over it and glued to the veneer. This is the better method of treatment in saw kerfing, but the saw kerfs may also be cut in the convex face of the stock, and when bent over the centre, a veneer may be glued over the convex surface to secure it.

33. Keying.—Fig. 24 shows another method of treating material requiring to be bent. In this method, known as **keying,** grooves of an even depth, as shown at *a*, are made in the back of the piece at suitable intervals (found as directed for space between saw kerfs), leaving an interior thickness of $\frac{1}{4}$ or $\frac{1}{8}$ inch, depending on the radius of curvature. These grooves are filled

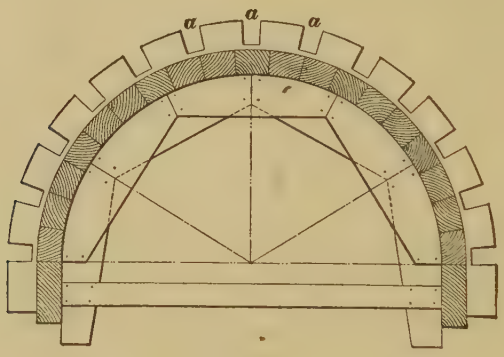

Fig. 24

with well-fitted wooden strips, called *keys*, plenty of glue having first been brushed into the grooves and over the keys. Two strips of veneer from 3 to 4 inches wide are glued and nailed over the convex face of the bent piece near each edge, and thus tend to strengthen the work materially. The ribs of the centre shown in Fig. 24 are in four parts, with bracing pieces nailed over each joint as shown.

34. Backing a Veneer.—Bending by **backing a veneer,** the third method, is shown in Fig. 25. Sufficient wood is planed from the back of the stuff to be bent to leave a veneer of the proper thickness and length between *r r*, the circumference of the semicircle. Then, when bent over the centre, the thickness is filled out, as required, by fitting and gluing cylindrical-faced staves *v* on the back of the veneer. These staves are made a trifle long, and each one after being fitted and glued has a long screw driven through its thickness to the centre, near each end, to hold it down and keep it in place until all are fitted and glued. To increase the strength of this curved piece of work, before

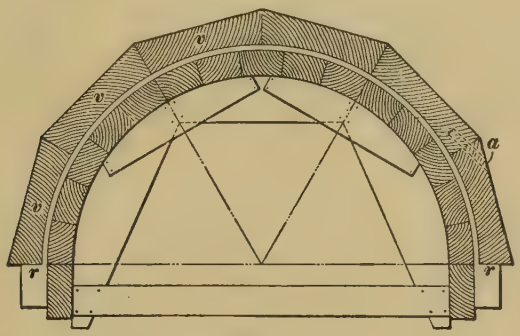

FIG. 25

taking it off the centre, the joints may be united by hardwood dowels, driven in and glued as shown at *a*.

35. Laminated Curved Work.—The fourth, or **laminating method,** as shown in Fig. 26, is a mode of bending and gluing together several layers, as shown at *a*, to make up the required thickness. All these layers should be fixed and glued over the centre at one operation, and, if possible, left there several days to dry. This is by far the strongest and best method for most purposes, but it will not do for mouldings, as the hardwood edges when cut into will show the streaks of glue ; this, however, would not be objectionable where the work is to be painted.

36. Steaming.—The fifth mode of bending is by **steaming.** Some woods bend easily when steamed, but all must be handled

with rapidity after steaming, no time being allowed for cooling until after the work is secured to the centre. A good steam box of suitable size should be prepared, and wet steam must be used, since dry, superheated steam makes wood brittle, but not flexible. To find the thickness of unprepared white pine that may be bent without injuring its elasticity, multiply the

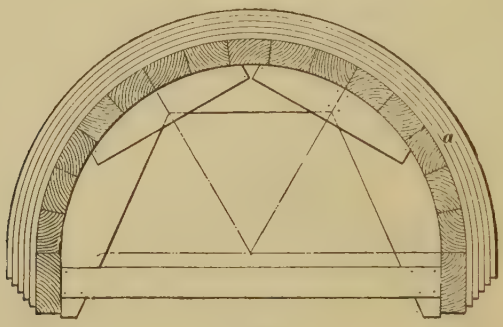

Fig. 26

radius, in feet, of the curvature required by the decimal ·05, and the product will be the thickness, in inches. For example, take a 5-foot radius; multiplying this by the given decimal, the thickness that will bend without fracture is $5 \times \cdot 05 = \cdot 25$, or $\frac{1}{4}$ inch.

VENEERING

37. Hardwoods, such as oak, ash, rosewood, etc., cannot be used in joinery work, if the pieces are of any considerable dimensions, unless they are backed up with some lighter or more reliable wood that is less affected by moisture or change of temperature. Hardwood, therefore, is often cut into thin slabs and glued to a piece of pine or other soft wood in such a manner that the finished work has the appearance of a solid block, while in reality its interior, or core, is of an entirely different material. This process is called **veneering,** and the thin slabs of hardwood are called **veneers.** It is a mistake to suppose that veneering is resorted to as a matter of economy, to save the cost of solid wood. Hardwoods are liable to warp

or twist out of proper shape ; especially is this the case with doors built of solid hardwood. Therefore, in order to make a good door and to secure the decorative elegance in colour and grain of the hardwoods, it often becomes absolutely necessary to employ veneering in door-making. Veneering, when properly executed with good glue, will last as long as the wood on which it is laid.

38. It is not good practice to use two kinds of wood in veneering a door ; as, for instance, one face mahogany and the other oak, or maple and cherry, oak and black walnut, etc. The varying conditions of heat and moisture act differently on the two kinds of wood, and the door has a tendency to warp. This is equally the case with a door where one face is in a warm room and the other face is constantly exposed to different atmospheric conditions, even though both sides of the door are veneered alike. If only one side of a panel is veneered, it will curl badly when dry ; consequently, both sides should be veneered.

The choicest and most beautiful veneers are cut from the crotches, and also, with some woods, from the roots of the trees, where the grain is gnarled, mottled, and attractively intermingled. These choice veneers are used on the surfaces of panels, and are highly polished to bring out the beautiful natural changes and colour qualities peculiar to the wood, relieved by the less-polished plain surface of the framework. The frame, or stiles and rails, is invariably veneered with plain, straight-grained veneers, finished flat.

39. Several valuable accessories to good veneering must not be overlooked. The first of these is a good heating box of length and width sufficient for long and short materials. Such a box may be cheaply constructed of plank, and lined with tin, with its cover, or lid, in three sections. The box should be piped and heated by steam, or, in the absence of steam, it may be heated conveniently by a 6-inch stovepipe carried through it lengthwise. In all cases, heated *cauls* are used against veneers to keep the glue hot, so that the wood may the better absorb it. During the several hours required for the glue to set, the caul also distributes the pressure of the handscrews evenly on the whole surface of

the veneers. A **caul** is a piece of wood or other suitable material, curved or straight, as the case may be, made to fit the surface to be veneered. When used for door stiles or panels, a thickness of 1 inch will be sufficient for the caul, but its width and length should never be less than that of the material to be veneered. To prevent the caul from sticking to the veneer, it should be coated with beeswax or paraffin, or, in the absence of these substances, brown paper cut to size and laid between the veneer and the caul will serve the purpose. Brown soap is sometimes used, but it frequently stains the wood.

40. Veneering a Door.—In Fig. 27 is shown a method of veneering a door in which the core is made of American yellow pine. The stiles are built up of several strips, the grain of each reversed with reference to that of the adjacent piece, and all glued together. The edges of the stiles, shown in Fig. 27 (*a*) and (*b*), have hardwood strips *h* glued on to form the outer

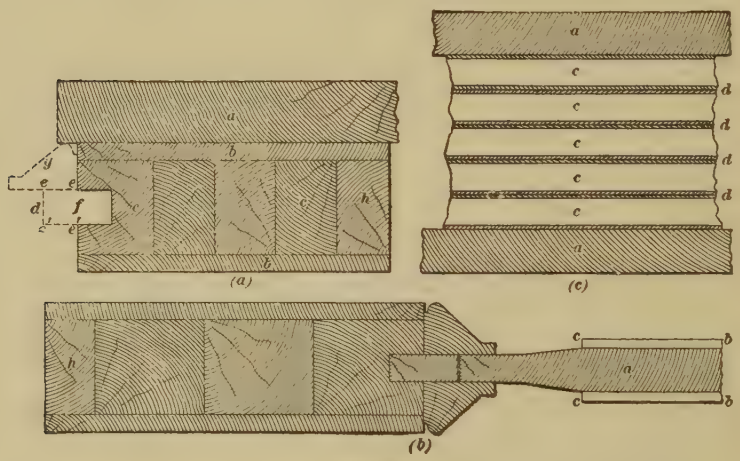

Fig. 27

edges. The stile is then faced straight out of wind and is well scratched lengthwise by means of a toothed plane; the veneer should also be scratched. The glue should be well cooked (if burnt it is useless), of a good body, and not too thick; plenty

of it should be brushed on the surfaces that are to be in contact, as the wood absorbs much of it.

In Fig. 27 (*a*) is shown a section through a door stile such as described ; the caul is shown at *a* against the veneer *b*, while the core is shown at *c*. Several stiles or rails may be veneered at one time with only outside cauls, but paper should be placed between the veneers. The veneers should be tacked in two or three places to keep them in position until clamped together with handscrews, which should be spaced not more than 6 inches apart ; in fact, they can hardly be put too close together. The handscrews are placed at opposite sides alternately, to ensure an even pressure on both edges that will drive the glue into the pores of the wood. In panelled work, where hardwood mouldings are used, it is desirable to avoid the use of nails to secure the mouldings in place.

41. At *f*, Fig. 27 (*a*), is shown a pine strip glued into the groove of the door stile, against which the panel mouldings *g* are mitred and glued at *e e* ; then the polished panels are set in place at *d*, and the other face of the door is moulded and glued to *e' e'*. Another example of door-stile moulding and panel is shown in (*b*). The panel *a* is usually made of the same kind of wood as the veneer, but plain. Sometimes, however, the raised face *b c* is veneered with choice wood of finely marked grain, polished and finished before it is placed in the door. All plain-faced material may be clamped and veneered together in quantities, as shown in Fig. 27 (*c*). The core pieces *c* are separated by layers of paper placed between the veneer faces, as shown at *d*, and one operation with the handscrews and the two cauls *a* is sufficient to secure the whole.

42. Thin veneers are often found in a badly crumpled condition. In this case, they must be sponged with hot water and squeezed gradually and evenly with handscrews between plain-surfaced cauls, and then allowed to stand until they are in a fit condition to be laid. Sometimes, the same effect is accomplished by placing heavy weights on a caul over the moistened veneers.

43. In order to join two pieces of thin veneer, they must be cut with a sharp knife guided by a perfect straightedge. The pieces are laid on a plane surface with paper underneath, and are tacked at a convenient distance on each side of the joint in such a way as to draw the two pieces together. Then, a strip of strong manila paper is glued over the joint, and the veneer is placed on a suitable straight strip of wood under heavy pressure and allowed to remain until the glue is dry. In laying this jointed veneer, the papered side must be laid outwards. After the veneer has been laid and the glue has become thoroughly dry, the paper may be slightly sponged and removed with the scraper.

44. The veneering of a small circular column may be accomplished with the apparatus shown in Fig. 28. Here, a sheet of tin is used. This sheet has cleats securely nailed to each end, by means of which handscrews can be made to press the heated tin caul and veneer tightly to the surface of the column. The tin

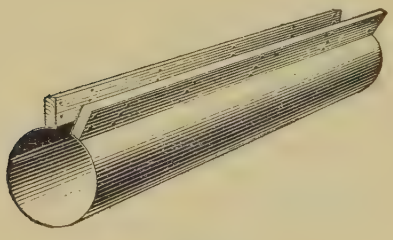

Fig. 28

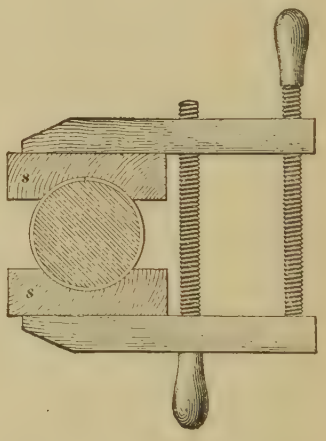

Fig. 29

should be about $\frac{3}{4}$ inch shorter than the circumference of the column, in order to leave room for the glue that is squeezed out along the joint. The veneer should be sponged with hot water just before straining it round the column. The column and the tin should be heated before veneering. The advantages of a tin caul are that it requires no waxing and will not stretch. A strip of paper wrapped round the core will be sufficient to determine

the length of the veneer, which must be equal to the circumference of the column. To bring the two edges of the veneer together when the tin caul is removed, long solid cauls are used, as shown at *s*, Fig. 29.

45. A tapering column is veneered in a precisely similar manner as a circular column. To find the length and shape of the veneer, however, set out, as in Fig. 30, *a b* equal to the height of the column, *c d* equal to the diameter of base, and *e f* the diameter of the column at the top. Continue *d e* and *c e* to *i*. From *i* as a centre, with *i c* and *i e* as radii, describe the arcs *c h* and *e f*; from *a* as a centre, describe the semicircle of the base *c d*. Divide the semicircle into any number of equal parts, and mark these parts twice on the unfolded base line *c h*; connect *h i*; then, *c h f e* will be the shape and exact length of the veneer and also of the caul. The caul, however, must be made to come together about $\frac{3}{4}$ inch short, as previously explained.

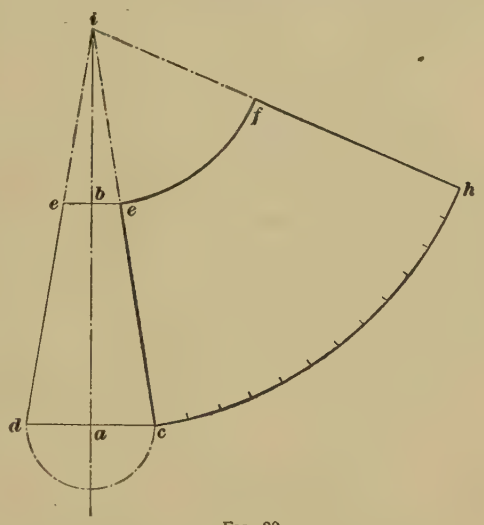

FIG. 30

DOORS

DESIGN AND CONSTRUCTION

46. A door is a simple piece of panelled work, but the great variety of form and arrangement of its panels and the enrichment of its mouldings, together with the conditions arising from its

method of opening or closing, require it to be even more securely framed and glued than a wainscot or other piece of fixed panelled work. The swinging of a door on its hinges brings a great strain on the joints in the stile on the hinge side, whereas a sliding door hung from the top has its entire weight suspended.

47. Sizes of Doors.—The width of a door is regulated by the purpose for which it is intended, so that in public buildings provision is made for the free passage of several persons at the same time, while in private houses and offices a width suitable for one person is considered sufficient. In the former case, the width may be from 6 feet upwards, while in the latter, the general rule places the minimum width at 2 feet 8 inches for communicating doors and 2 feet or 2 feet 3 inches for closet doors. Where a folding, or hinged, door must be more than 4 feet wide, it should be made double, that is, in two folds. Since double folding doors in apartments take up considerable wall space when opened, it is preferable to substitute *sliding doors*, or doors that slide into pockets provided for them in double partitions.

48. The proportion between the width and the height of doors at main entrances and in public buildings is usually as 1 is to 2 ; that is, the height is equal to twice the width, this being the rule adopted in classic structures. For single doors in dwellings and offices, the proportion should be as 1 is to $2\frac{1}{2}$; that is, the height should be equal to $2\frac{1}{2}$ times the width. Doors 2 feet 8 inches by 6 feet 8 inches and 3 feet by 7 feet 6 inches would thus look in good proportions. Where there are several doors of different widths in the same apartment, it is better to fix the height of the principal doors by the proportion given and make the others of the same height, which gives a better effect to the interior treatment. Where the width of double folding or sliding doors does not exceed 6 feet, their height may be that of the principal doors ; but where wider than this, their height should be made one-fourth more than the width ; for example, a door 8 feet wide should be 10 feet high. The width that can be given to sliding doors, however, is regulated by the depth that can be secured for the pocket in the partition.

49. Construction.—As a door made of one wide board would shrink and warp too much, the expedient is adopted of matching, or grooving and tongueing, several pieces together. These are held in place and stiffened with two or three bars on the back. Where such doors are over 2 feet 6 inches wide, it is necessary to further stiffen them with diagonal bars or braces to prevent them from sagging. Such doors are used in inferior situations in the dwelling, or in the workshop, but, when well made, are strong and durable. They are classified according to their methods of construction.

50. The most serviceable door is one in which the framing is mortised and tenoned together and the surface between the inner edges of the outer stiles and the top rail is formed with matched-and-beaded lining. As the outer stiles and top rail are grooved, or rabbeted, to receive the lining, the intermediate framing is this thickness less than the stiles. The panelled door is the most approved form for general use, and a great variety of beautiful effects are produced by the artistic treatment not only of the moulded framing and the moulded and relieved panelling, but also of the materials of which the door is constructed.

In this door, provision is made for the expansion and contraction of the wide portions of the woodwork, but the portions that are closely united are made narrow in width as much to avoid changes due to the temperature as to secure economy in the use of material. The requirements to be fulfilled are a rigid structure that will remain firm and compact under usage and yet be sufficiently light in weight to be readily moved. The width of the framing should be about one-ninth the width of the door, and the bottom rail about one-tenth the height; the thickness will depend somewhat on the style of finish and the class of lock to be used. If a rim or surface lock is to be used, the door may be somewhat less thick than if a mortise lock is required; as an illustrative case, a chamber or wall-press door may be made $1\frac{1}{4}$ inches thick, if the former lock is used, but it should not be made less than $1\frac{1}{2}$ inches thick in the case of a mortise lock.

LEDGED AND FRAMED DOORS

51. Ledged Door.—In Fig. 31 (*a*) and (*b*) are shown, respectively, the elevation and plan of the simplest form of door, called a **ledged door.** This door is made up of three ledges,

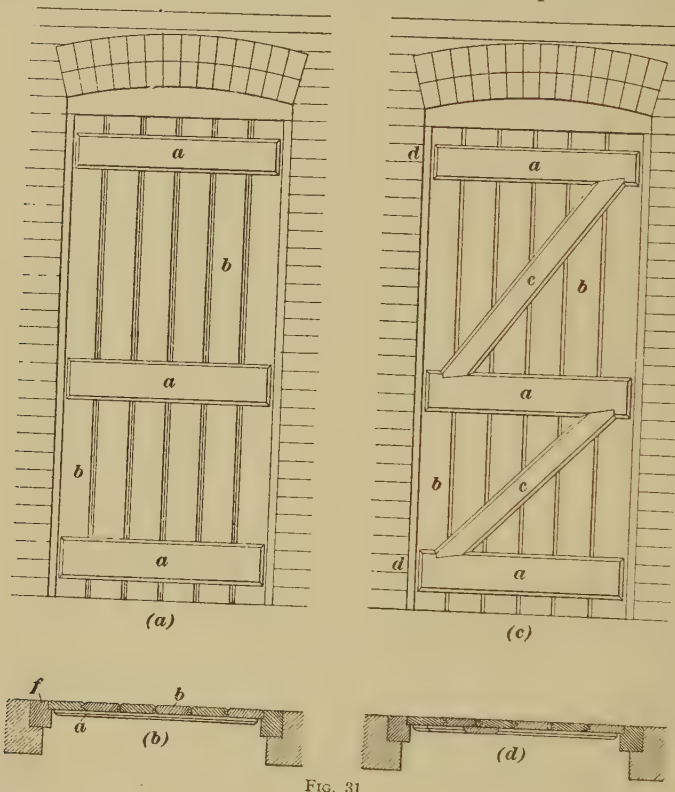

FIG. 31

or back bars *a*, usually from 6 to 10 inches wide by about 1 or $1\frac{1}{4}$ inches thick. To these is nailed matched boarding *b b* from $\frac{3}{4}$ to 1 inch thick. The ledges *a* are very often splayed or beaded on the edges as shown. The door is generally hung to the frame *f*, Fig. 31 (*b*), by means of *cross-garnets*, or *strap hinges*, bolted through the ledges. This door is only suitable for use in outside sheds or farm buildings.

52. Ledged and Braced Door.—The door shown in Fig. 31 (*c*) and (*d*), known as the **ledged and braced door**, is similar to the ledged door, except that it is strengthened by the braces *c*, *c*. The hinges should be fastened to the frame on the edge of the door shown at *d*, *d*, as in this way the bracing keeps the door from sagging or twisting. As before, the ledges are shown at *a*, the matched boarding being shown at *b*.

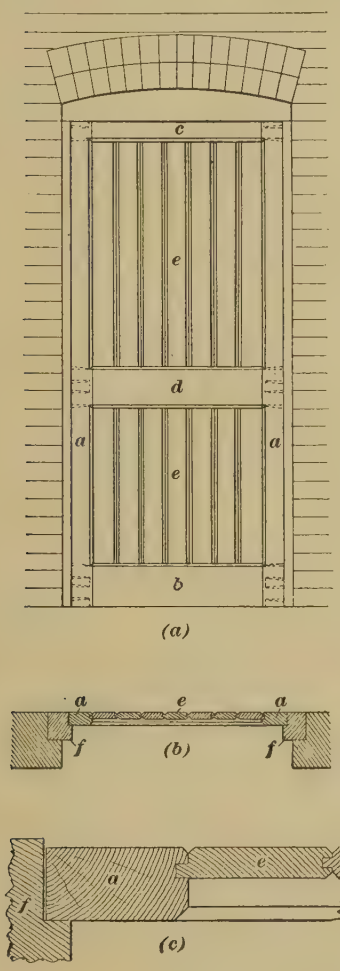

Fig. 32

53. Framed and Ledged Door.—A type often used for outside doors in a house, to back kitchens, sculleries, etc., is the **framed and ledged door.** It is made, as shown in Fig. 32, of two vertical stiles *a*, *a* with bottom rail *b* and top rail *c*, Fig. 32 (*a*), tenoned into them. The matched boarding *e* is grooved and tongued into the stiles *a*, *a*, as shown in Fig. 32 (*c*), but it is not tongued and grooved into the lock rail *d*, but runs over it, consequently the lock rail is not so thick in section as the top and bottom rails. The sizes of the material used for this door vary considerably with the size of the door, but for a door about 3 feet wide, 4″ × 2″ stiles, 7″ × 2″ bottom rails, 7″ × $1\frac{1}{8}$″ lock rail, and 4″ × 2″ top rail, would be quite usual. The door is hung to a rabbeted frame *f*, Fig. 32 (*b*), in a similar manner to the ledged door, or with ordinary butt hinges.

54. Framed Ledged and Braced Door.—A door constructed like the framed and ledged door, but with the addition of the braces shown at *f*, *f*, Fig. 33 (*a*), is the **framed ledged and braced door.** The stiles are shown at *a*, the bottom rail at *b*, the lock rail at *c*, the top rail at *d*, and the matched boarding at *e*. A door of this description is often used in dwelling houses, for access to the garden from the kitchen or scullery, and makes a very strong and good-looking door. The stiles, rails, and braces are chamfered on their edges, and these chamfers are stopped where they abut on another rail or stile. The boarding is continued down to the bottom of the door, the bottom rail and lock rail thus being of the same thickness. In Fig. 33 (*b*) is shown the plan of this door built in a $13\frac{1}{2}$-inch wall. The frame *g* is rabbeted and the door hung to it by means of ordinary hinges. The inside plastering of the wall stopped against the door frame is shown at *h*, *i* being a small moulding that is often fixed to the door frame to cover the joint between the plaster and the wood.

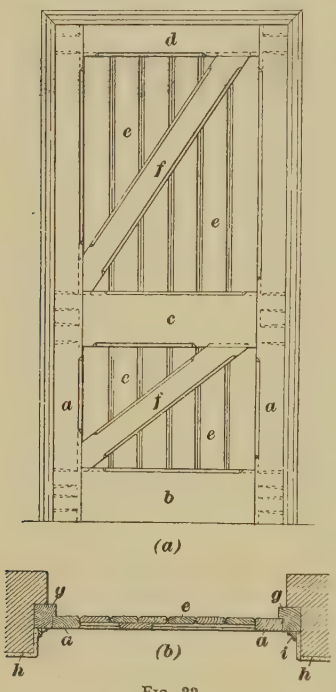

FIG. 33

55. Door and Fanlight.—In Fig. 34 (*a*) is shown the elevation, from the outside, of a framed ledged and braced door with a fanlight *a*. Fig. 34 (*b*) is a detail section through the head of this door and fanlight, *a* being the top rail of the door, *b* the moulded transom over the door, *c* the fanlight, and *d* the door frame. Fig. 34 (*c*), (*d*), and (*e*) are the plan, elevation, and section through the door and lock rail to a larger scale. In (*c*) is shown the plan where *a* is the matched boarding, *b* the stile

of the door, *c* the rabbeted and moulded frame to which the door is hung, *d* the plastering on the wall inside the door, and *e* the

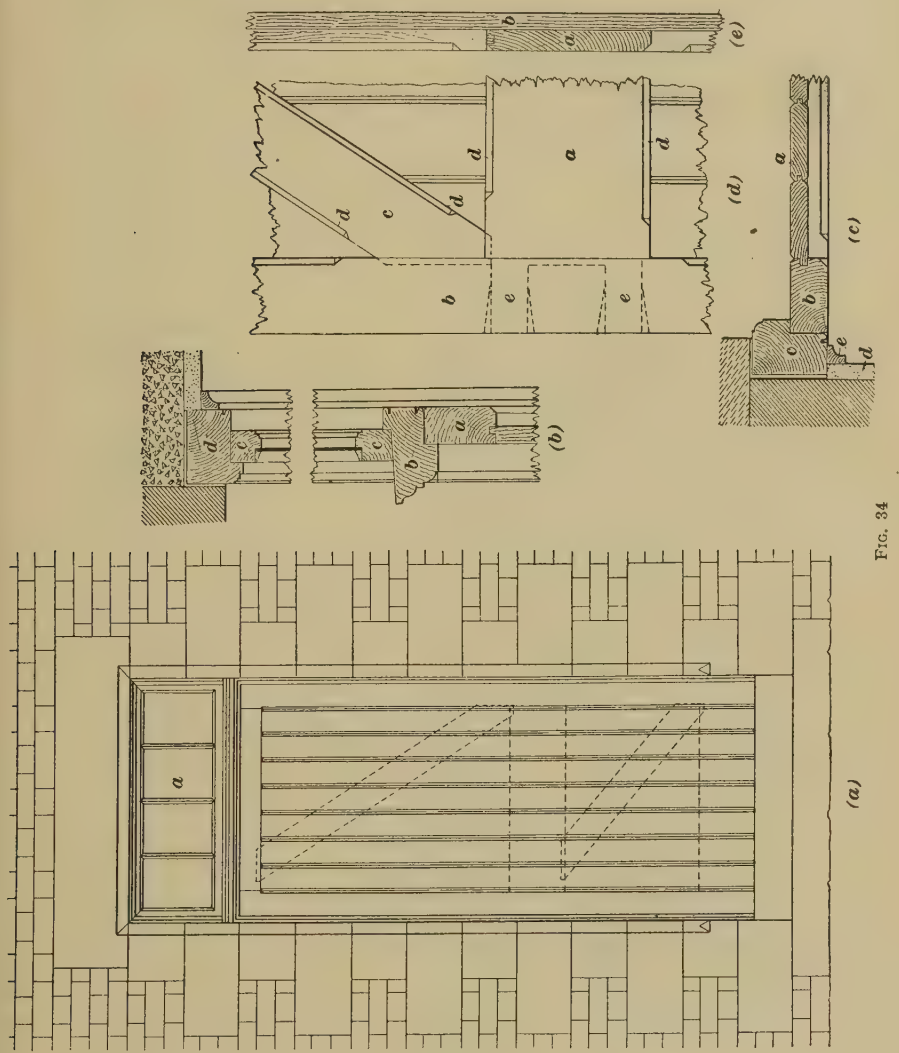

FIG. 34

small moulding to cover the joint. In (*d*) is shown an elevation of the lock rail *a* and stile *b* of the same door, *c* being the brace.

The edges of all these are stop chamfered, as shown at *d*. At *e*, *e* are shown the tenons of the lock rail inserted in the stile. In (*e*) is shown the section through the lock rail *a*, where *b* is the matched boarding running over it.

PANELLED DOORS

56. Panels and Mouldings.—In panelled doors, the proportions and design of the panels and mouldings vary greatly. The lock rail, however, should not be too low for a person to reach the lock without stooping, nor too high for one to grasp the knob without reaching. The usual height to the centre of the knob of the lock is about 3 feet from the floor, but this dimension is varied considerably by architects. The lock should be mortised into the stile between the tenons of the lock rail or immediately above them, in order not to destroy the tenons when the lock is inserted. A better method is to put in a lock panel from 6 to 7 inches wide; this is accomplished by practically cutting the lock rail in two in the width and inserting a panel between the sections, as shown in Fig. 35.

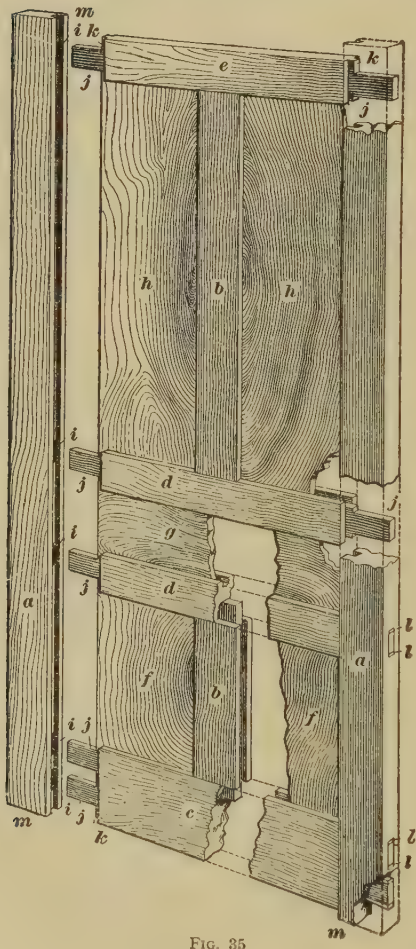

Fig. 35

57. The moulding round the panels of doors may be a simple ogee worked on the edges of the stiles and rails of the framing, and when worked in this way is known as **stuck, or solid moulded.** Mouldings of any desired form may be inserted in the angle between the edges of the stile or rail and the panel, as shown in Fig. 36, but care must be taken that the nails pass into the edges of the framing and not into the panels, as the shrinkage of the panels will pull the moulding away from the framing. Such mouldings in good work should be glued to the edge of the framing.

58. Mouldings.—In Fig. 36 (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*) are shown six methods of finishing mouldings round the panels of doors. In each case the panel is shown at *a*, the stile of the door at *b*, and the moulding at *c*. In (*a*) is shown a very usual

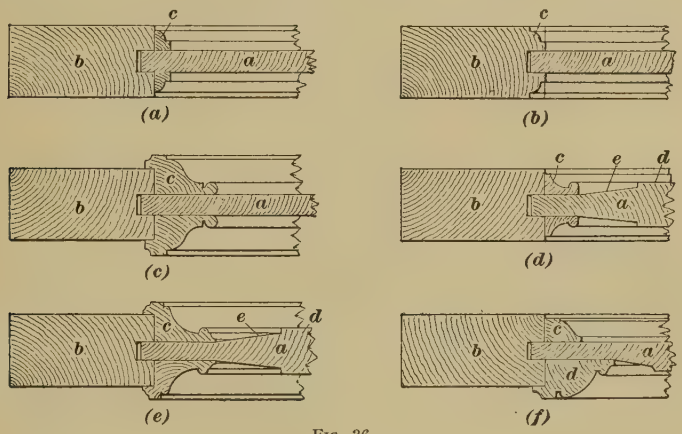

FIG. 36

form of door panel, where the panel itself is housed into the stile of the door and the panel mouldings are *planted* on. In (*b*) is shown a similar construction, but in this case the mouldings are worked on the solid of the stile. In (*c*), a panel is shown with mouldings projecting beyond the face of the stile and rabbeted at the back to cover the joint between the stile and the panel ; this is called a **bolection,** or **raised planted, moulding.** In (*d*) is shown a construction similar to that in (*a*), except that the panel has upon it a raised projection *d*, and the edges

of the panel next to the moulding are sloped out to meet this projecting face, as shown at *e* ; this is called a **raised-and-mitred, or fielded, panel.** In (*e*) is shown a still more elaborate treatment, in which there is a raised-and-mitred panel with bolection moulding round it. At (*f*) is shown the construction often employed for a front entrance door, where the outside has a bolection moulding *d* and raised-and-mitred panel *a*, and the inside is kept plain with a simple stuck moulding *c*. It will, of course, be understood that any moulding can be used in the design of a door, and numerous forms of door panels can be designed by modifying the proportions of some of the types shown.

59. Five-Panelled Door.—The mode of constructing a **five-panelled door** is shown in Fig. 35, in which certain parts are removed so as to show the joints. The introduction of the lock panel provides for the insertion of a mortise lock without injuring the adjacent joints. In this illustration *a*, *a* are the outer stiles ; *b*, *b*, the central stiles, or muntins ; *c*, the bottom rail ; *d*, *d*, the lock rails ; *e*, the top rail ; *f*, *f*, the lower panels ; *g*, the lock panel ; and *h*, *h*, the upper panels. The mortises *i* are made one-third the thickness of the framing, into which the tenons *j* are fitted. The edges of the framing are grooved $\frac{1}{2}$ inch to receive the panels, the width of the groove being the same as the thickness of the tenon. The upper edge of the tenons of the top rail and the lower edge of the tenons of the bottom rail are haunched, as shown at *k*, in order to obtain a compact mortise ; otherwise, the stiles would be cut in two at those sections. The bottom rail has double tenons with a bridge between the mortises, which secures compact mortises and does not unnecessarily weaken the stiles. The central stiles are mortised into the rails. As a provision for expansion, the panels must be kept from $\frac{1}{8}$ to $\frac{3}{16}$ inch less than the width of the space between grooves. If the panels are fitted tight and the doors are put in place before the plastering is thoroughly dry, or the building is shut up for some time during damp weather, the panels will first assume a dishlike shape by expansion or swelling, which, if excessive, will exceed the tensional value of the tenon and force the stile from its position by tearing the fibres apart.

60. Where the door is to be varnished, care should be taken to arrange the parts before they are assembled so that the grain of the timber shall be naturally placed ; in other words, so that the leaf grain will be disposed to show an upward growth, and that in the panels will be adjacent to the centre stiles. For fine work, straight-grained framing and curly panels give the best results and a pleasing and agreeable harmony of tone.

61. In putting the door together, only the shoulder, or that portion of the tenon next to the panel, should be glued, so that, in the event of shrinkage or swelling, the joints will remain close and intact. When the stiles are driven up and the cramps applied, the wedges *l*, Fig. 35, should be well fitted, the edges next to the tenons should be brushed with glue, and they should be driven in tightly. The horns *m*, or the extra lengths of the stiles during construction, are designed to withstand the pressure exerted when the end wedges are driven in. Otherwise, the wood beyond the mortise would be forced out by shearing of the fibre, thus destroying the joint.

62. Dowelled Framing.—In some cases, the framing of panelled work is put together with dowels, as shown in Fig. 37. These dowels vary from $\frac{3}{8}$ to 1 inch in diameter, according to the thickness of the wood to be united, but in any case they are considerably thicker than a mortise would be in the same material. Along the edge of each dowel a **V**-shaped groove is cut, as shown at *a*, to allow the air and surplus glue to escape when the parts are driven together.

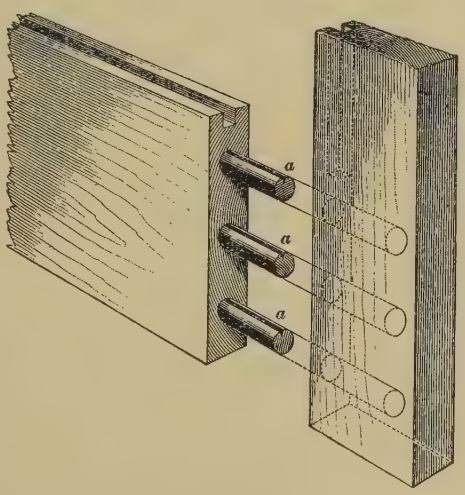

Fig. 37

FIG. 38

63. Sliding Doors.—Sliding doors differ from ordinary swinging doors chiefly in the method of hanging them, and, as the strain of their parts is reduced or increased with the different methods, a corresponding alteration of the details of their framing is necessary. Fig. 38 (*a*) shows one of a pair of sliding doors, intended to be hung from the top. In a door hung in this manner, the stile is not subjected to so much strain as when the door is hung on the side. Where a sliding door is hung with the patent stile hanger, which brings the entire weight on the stile, particular attention should be given to the mortises and tenons in the hanging stile to ensure a perfect fit, as the slightest loosening will cause a sag in the door and thus prevent smooth running. In the plan of the door, Fig. 38 (*b*), the meeting stiles of both doors are shown, the edges of the rails being worked to fit together in a shallow tongued-and-grooved joint. This preserves the alinement of the doors when closed, and tends to prevent the appearance of a slit, or crack, between them, as would be the case if they simply butted together.

64. In opening, the doors slide into a pocket *d* built in the partition, as shown by the dotted lines *e*, *e*. This pocket is framed and finished in the same manner as a simple studded partition, except that the studs, or standards, are set in two rows with a space between them, $1\frac{1}{2}$ to 2 inches wider than the door is thick, so as to form the pocket *d*. The jambs of the door opening are then finished with a moulded facing, which is let into the jamb, as shown at *f*, and is allowed to project over the end of the pocket to within $\frac{1}{4}$ inch of the door. A stop is provided within the pocket, to prevent the door from sliding too far into the opening. The fittings on the meeting stiles of the door must be sunk flush with the face of the stile, so that they will not prevent the door from sliding clearly into the pocket. Numerous sliding-door locks and catches, made especially for this style of door, are provided by ironmongers.

65. Folding Doors.—Folding doors consist of a pair of single doors hinged on opposite sides of the opening. They are provided with a stop-bead or a rabbeted stile, so that they will close together in a tight joint at the middle of the opening. Fig. 39

FIG. 39

shows an elevation (*a*) and a plan (*b*) of a pair of folding doors. When this form of door is used as an inside vestibule door or a direct-entrance door, the panels *b*, as shown at *o* in the section *B″*, taken on the line *B B′* of the elevation, are often of glass; but when used for outside doors, the transom only may be glazed, so as to admit light to the vestibule when both doors are closed. The plan at *A″* of the door is taken on the line *A A′*, and shows the two lower panels at *p*, *p*. The framing of the stiles and rails of folding doors is precisely the same as for single swing doors, but the meeting stiles must be rabbeted, as shown at *c*, so as to provide a stop against which the more frequently used door may close.

This rabbeted stop must be bevelled off slightly on the inside, to give proper clearance to the outside angle of the door when it is opened. The amount of bevel necessary in order to accomplish this clearance is found by striking a circular arc *j k* with a radius *k l* equal to the diagonal distance from the corner *k* of the door to be cleared to the centre of the butt pin *l*, and with a centre at the latter point.

66. Entrance Doors.—In Fig. 40 (*a*), (*b*), (*c*), (*d*), and (*e*) is shown the detail of a pair of entrance doors suitable for a town house. In (*a*) is shown one-half of the inside elevation of the doors, while in (*b*) is shown one-half of the outside elevation. In (*c*) is shown a section through the doors taken on the centre line, and in (*d*) is shown the plan. At *a*, in each case, is shown the brick wall, $13\frac{1}{2}$ inches thick, into a reveal in which is bedded the frame *b* to which the doors are hung. At *c* is shown the rabbeted transom over the door, over which is the fanlight *d*. In (*e*) is shown a section through the head of the door and panels, to a larger scale, showing the construction. The frame *b* of the door is carried round the circular opening to form the head over the fanlight, *c* being the transom, moulded and rabbeted to take door and fanlight. This fanlight is fixed, but it may be made to open with a slightly different construction so as to keep out the wet. At *e* is shown the top rail of the door, at *f* the section through the panel with a moulding planted on the same, and at *g* a section through the lower panels of the door, which

are bolection moulded with raised and mitred panels. In (*e*),

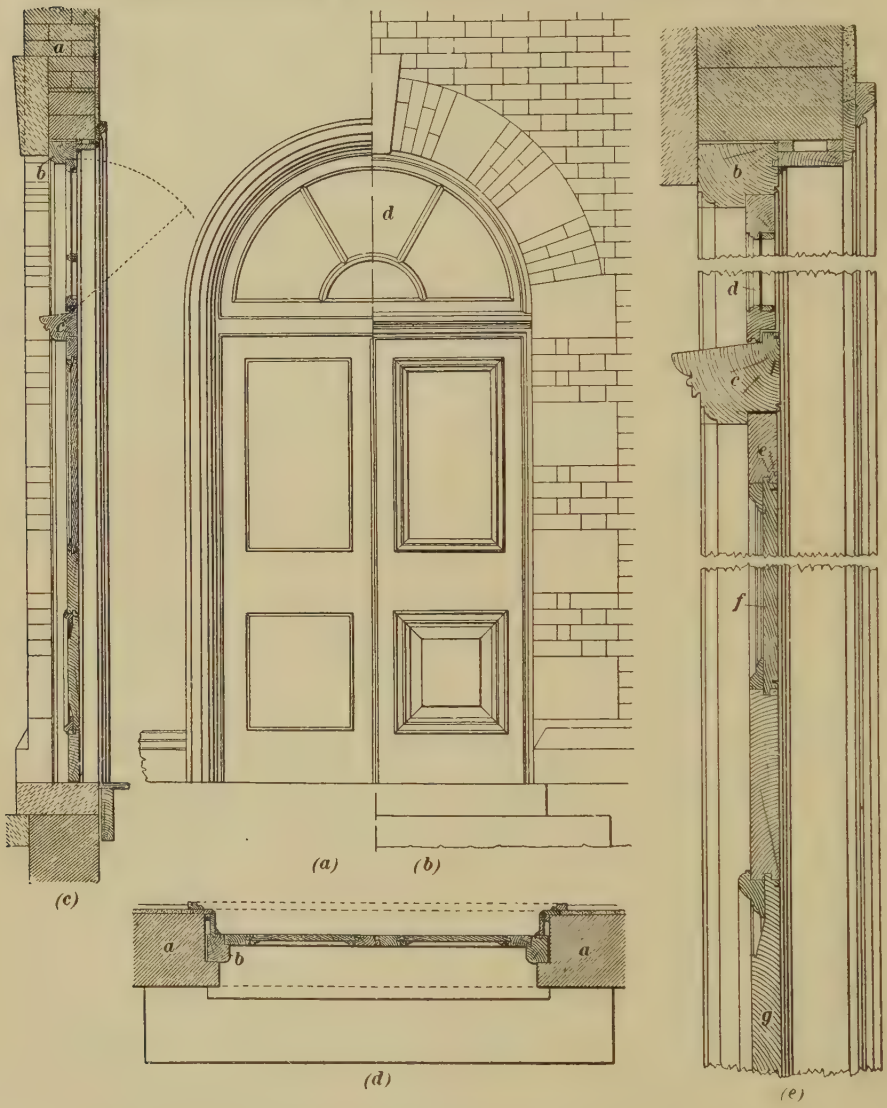

Fig. 40

at *f* and *g* the panels are shown flush on the inside of the door,

with a small moulding formed on their edges to hide the joint next the stiles and rails. By this means the panel can be made thicker, which is necessary for an external door exposed to all changes of the weather, and the greater setback, or recess, from the stiles of the door gives a pleasing effect in the design.

METHODS OF HANGING DOORS

67. Doors are usually hung by means of hinges, or butts, to linings or frames, according to the position of the doors in the building and the thickness of the walls in which the doors occur. External doors are usually hung to frames, while doors

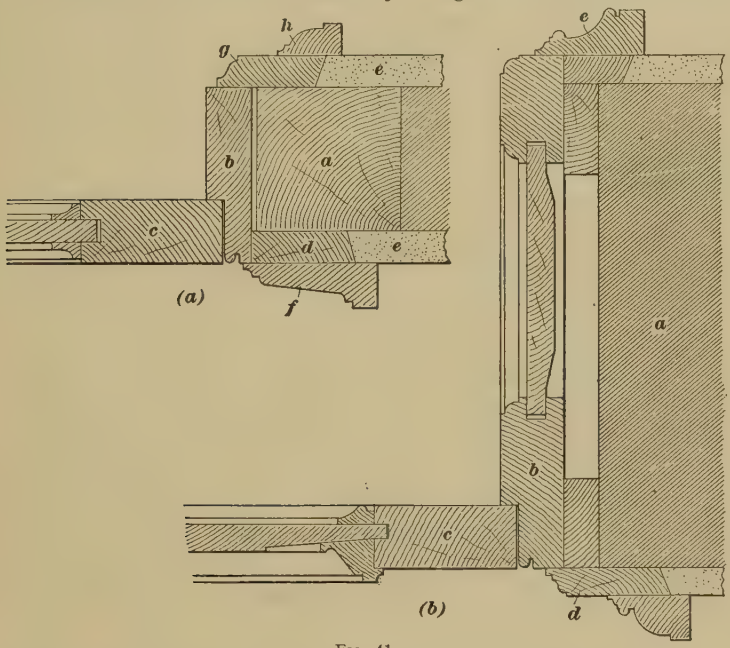

Fig. 41

in framed partitions are generally hung to linings, which may be plain or framed, that is, they may be worked out of one piece of wood or may be built up of several pieces. If linings are wider than 13 or 14 inches, they are usually panelled. In Fig. 40 is shown the method of hanging a door to a frame.

In Fig. 41 (*a*) and (*b*) are shown two methods of hanging a door to linings. In (*a*) is shown a plain lining, used for door openings in framed wooden partitions and thin brick walls, *a* being the framing timber of the partition, *b* the rabbeted lining, *c* the panelled door, and *d* a rough ground of the same thickness as the plaster *e*, nailed to the rough frame, as a stop to the plaster, and for the purpose of giving a fixing for the architrave. To cover the joint between plaster and ground and make a satisfactory looking finish, a moulding *f*, called the *architrave mould*, is fixed to the rough ground round the door opening. At *g* is shown a ground used for a similar reason as a rough ground, but in a different way. This is wrought or planed smooth and moulded, and a smaller architrave *h* is fixed to cover the joint between plaster and ground. In (*b*) is shown a lining suitable for a thicker wall : *a* is the $13\frac{1}{2}$-inch brick wall, *b* the panelled lining, *c* the door with raised-and-mitred and bolection-moulded panels on one side ; at *d* is shown a finish with wrought and moulded ground, and at *e* is shown a finish with a rough ground.

In some cases the door is hung direct to the framing timber of the partition, as shown at *a* in (*a*). When this is done, the framing timber must be wrought or planed to a smooth face, a stop or narrow lining strip being fixed to it up to the face of the door to form a rabbet for the door to shut against.

68. Great care must be taken when hanging a door that it swings easily on its hinges ; when shutting it, the edges should just fit against the rabbets of the linings, or frame, and should not jamb or rub anywhere, or else, in time, a very unpleasant appearance due to the rubbing of the paint or other finish will be the result. The door should not, on the other hand, fit too loosely in its frame or lining, or draughts will result.

HINGES AND THEIR APPLICATION

69. **Butts,** or hinges, are used for hanging doors, inside shutters, lids of chests, boxes, etc. The butt sometimes used for hanging doors is a *loose-pin butt ;* the pin being loose, it

can be readily taken out with the fingers, and the door can thus be removed without unscrewing the hinges. To hang the door properly, two hinges, and, in case of heavy doors, three hinges, are required, the top one being secured 6 inches below the top of the door, and the bottom one 10 inches above the bottom of the door. Fig. 42 (*a*) shows a horizontal section

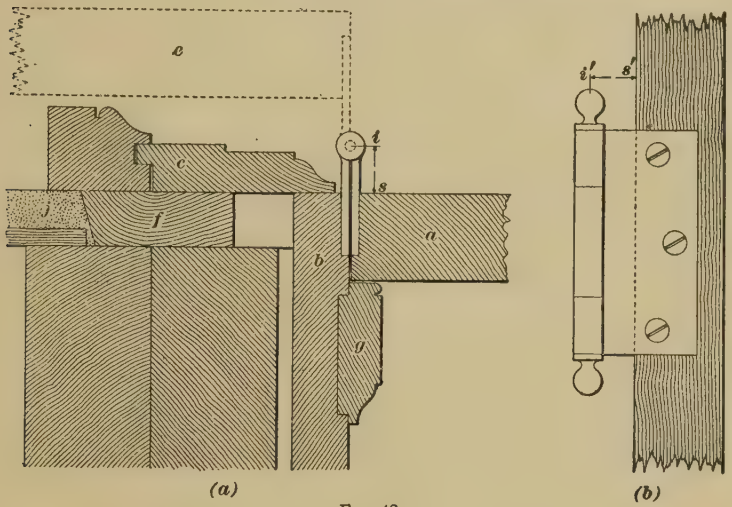

Fig. 42

through a door casing at the hinge. At *b* is the door lining, at the back of which are the grounds *f* extending to the plaster line *j*. At *c* is shown the architrave, built up in two pieces, and at *g*, the door stop against which the door *a* is closed. This shows another method of forming a lining to which a door can be hung. The projection *s i* of the hinge to the centre of the pivot is the same as *s' i'* of the hinge shown in the elevation (*b*), where one flap of the hinge is shown let in and screwed to the edge of the door. This projection *s' i'* of the hinge, when the door is opened, as shown dotted at *e* in (*a*), causes the door to swing twice the distance *s i*, thereby causing it to clear the architrave *c*, a condition always requiring consideration when hinges are ordered.

JOINERY

(PART 2)

WINDOWS, ROOF LIGHTS, AND INTERNAL FINISHINGS

WINDOW DESIGN AND CONSTRUCTION

INTRODUCTION

1. Windows are openings in the wall of a building to admit light, or light and air. Their form, number, and size depend on the character of the building. In residences, where the main object is to secure light and ventilation, some form of sash or casement window is used. In shops and warehouses, where the windows are generally used for the display of goods, the windows assume the character of showcases and have no sashes or frames except those necessary to hold the glass in place.

The proportion of window surface to wall surface is given by various authorities as :

One-eighth of the wall surface should be windows ; the area of glass should equal at least one-tenth of the floor area ; 1 square foot of glass should be allowed to each 100 cubic feet of interior space to be lighted. It is better to have a surplus than a deficiency of light, for if too bright the light can be regulated by blinds or shutters. For buildings of any pretensions, it is a mistake to cut up the sash into small panes ; windows are designed for the purpose of lighting, and all obstructions created by sash bars or astragals detract from the desired result. Where

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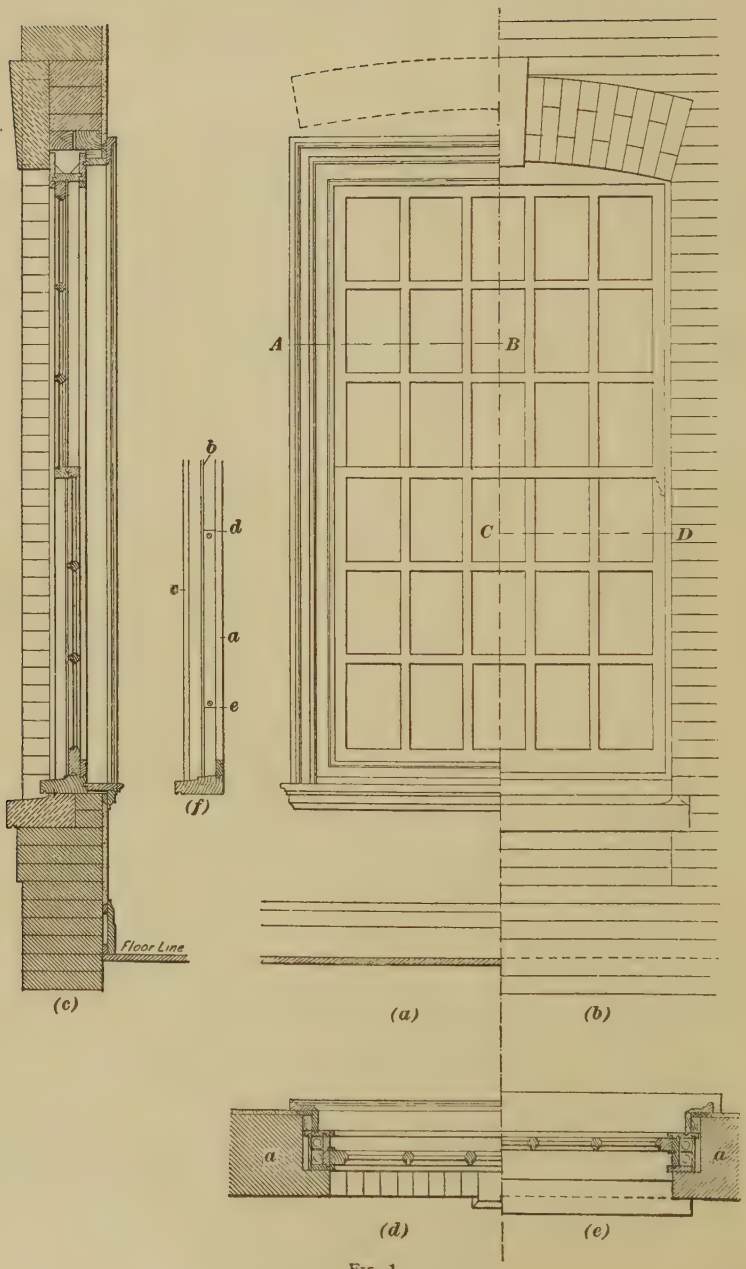


Fig. 1

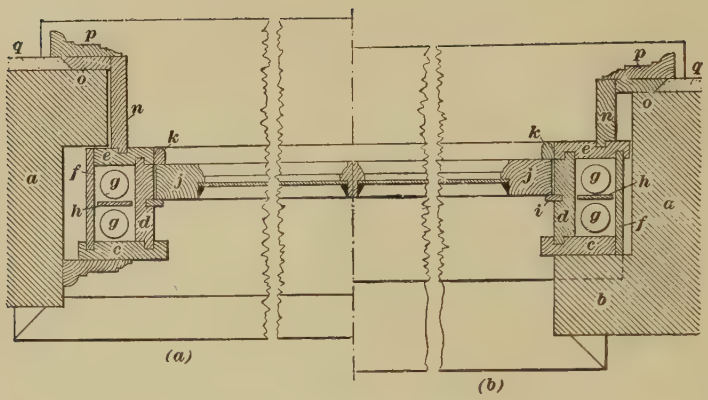
the designer prefers to have the window sash subdivided, iron, zinc, copper, or lead bars should be used, for they are more durable than wood, and do not take up so much of the daylight area.

2. Windows may be divided into two general classes: those having fixed sashes and those with movable sashes. The latter class may be hinged, pivoted, or balanced, as the case may require. The frames may be put in as the walls are being built or just before the plastering is commenced. To ensure a thoroughly sound water-tight window, sashes should slide vertically, being counterbalanced by means of cord, or chain, and weights, or by spring sash balances. Those which are hinged at the sides and open inwards are difficult to make thoroughly water-tight, and those opening outwards are likely to be injured by the action of wind. Sash stops should be fastened with screws passing through slotted sockets, thus preventing the sashes from rattling and warping. The Building Regulations of some cities require all upper-floor windows to be fitted with an apparatus that will allow the sashes to be opened inwards for cleaning purposes. There are many patents on the market for this purpose.

DOUBLE-HUNG SASH WINDOWS

3. Double-Hung Sash Window With Interior Finishings. When a window frame in a brick or stone wall is to be subsequently finished on the interior, the details must be carefully considered in order to make the frame fulfil the requirements. In Fig. 1 (*a*) is shown half the interior elevation of a double-hung sash window; in (*b*), half the exterior elevation; in (*c*), the section taken through the centre of the window; in (*d*) the plan taken on the line *A B*; and in (*e*) the plan taken through the lower sash on the line *C D*.

In Fig. 2 (*b*) is shown a detail, to a larger scale, through the weight box, giving full details of its construction. The brick wall *a* is $13\frac{1}{2}$ inches thick with a reveal at *b* of $4\frac{1}{2}$ inches. The outside lining *c* of the sash box, usually about 1 inch thick, has a groove in which is placed the tongue of the pulley stile *d* about $1\frac{1}{4}$ inches thick. The tongue of this is, in turn, placed in a groove in the inside lining *e*, which is 1 inch thick. When covered with



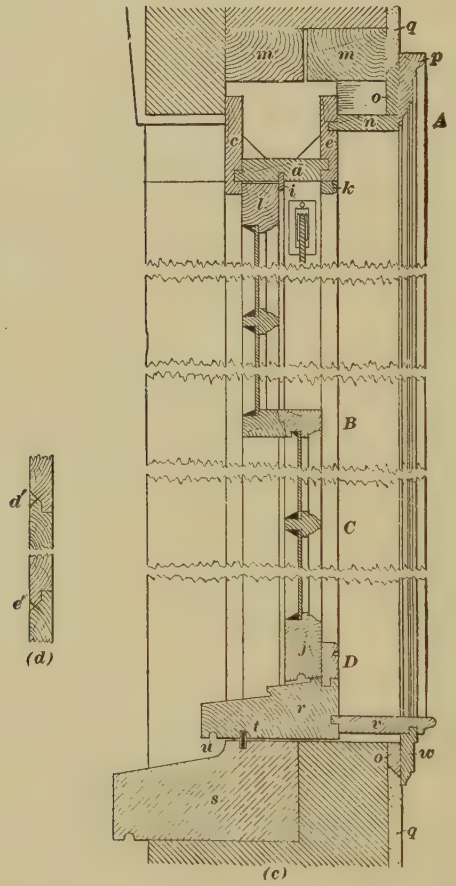


FIG. 2

the back lining *f*, these three pieces form a box in which are hung two sash weights *g*, *g*. When the weights are large, or the space containing them is limited, the weights are separated by a wooden tongue *h*, so as to prevent them striking together when the sash is raised or lowered. The pulley stile is grooved on its face to receive the parting bead *i* which, with the $\frac{1}{2}$-inch or $\frac{5}{8}$-inch projection, secures the upper sash in its place and provides a way in which it may slide. This parting bead is often made of hardwood, from $\frac{1}{2}$ inch by 1 inch to $\frac{5}{8}$ inch by $1\frac{1}{4}$ inches in section, and is only nailed in place so that it can be removed when for any reason it is desired to take out the top sash. The lower sash *j* slides inside the parting bead and is secured in place by means of the stop-bead *k*, which is made movable and which projects about $\frac{5}{8}$ inch in front of the face of the pulley stile.

4. In Fig. 2 (*c*) is shown a section through the window to a large scale. The head or top of the window frame is shown at *A*. Here the outside lining is carried across the top of the opening, as shown at *c*. The window head *d* is let into the inside and outside linings *e* and *c*, and ploughed to receive the parting strip *i*. The stop-bead *k* is mitred in the angle and returned across the top of the frame. At *l* is shown the top sash ; at *m*, *m*, the wooden lintels over the head of the window to relieve it of the weight of the brickwork. At *n* is shown the inside lining of the window grooved into the inside lining *e* of the frame and fixed to the rough ground *o*, which is spiked to the wooden lintel, or to blocks fixed to the under side of the lintel as shown. The plaster *q* on the brick wall is stopped against this rough ground, and the joint between plaster and ground is covered by the architrave moulding *p*, which is mitred round the window opening.

At *B* is shown the meeting rail of the two sashes, as they appear when the window is closed ; they are very often rabbeted, as shown, to prevent draught. The section through the astragal, or glazing bar, is shown at *C*, and at *D* is shown the detail through the sill of the window. Here *j* is the lower sash and *r* is the oak or hardwood sill.

There is a break, or step, in this sill just below where the stop-bead meets it, to prevent water blowing up its face under the sash. The sill *r* rests on the stone sill *s*. When set, the sill is laid on a bed of mortar spread over the stone sill *s*, and this mortar, being forced into the groove *t*, makes a perfectly water-tight joint between the two sills.

5. A metal strip, called a **water bar,** is often inserted in a groove made in the stone sill directly under the groove in the wooden sill. This strip is bedded in mortar when the sill is set, thus effectually keeping water from penetrating into the joint. Unless some such device as this is adopted, the slightest shrinkage or warping of the sill will allow the passage of air and water. A drip or throat *u* is often made in the wooden sill to throw the water running down it away from the joint. At *v* is shown the window board grooved in the wooden sill to form a finish over the brick wall ; *q* is the plaster on the inside face of the wall ; *o*, the rough ground ; and *w*, a moulding grooved in the window board and fixed to the rough ground to cover the joint between it and the plaster.

6. In Fig. 2 (*a*) is shown a plan through the sash box of a window where the box is placed in a different position in relation to the brick reveal. The inside lining *e*, the outside lining *c*, the pulley stile *d*, and the rest of the frame are constructed exactly like that shown in Fig. 2 (*b*). But as the frame is kept farther from the reveal a moulding is placed on the outside of the frame, fitted close to the brickwork, and mitred right round the brick opening to cover the joint. Sometimes, instead of this moulding, a squared piece is placed to which outside shutters can be fixed. When a window is fixed in position in a wall, it is often necessary to gain access to the weights in the sash box. This is done by forming in one side of the pulley stile, a *pocket*, which is an opening cut in the pulley stile and closed by means of a bevel-edged board secured in place by screws.

In Fig. 1 (*f*) is shown an elevation of the pulley stile without the sashes, where *a* is the inside stop-bead ; *b*, the parting bead ; and *c*, the outside lining. At *d e* is shown the opening to the weight box. A section through the pocket cover is shown in

Fig. 2 (*d*) where the lines *d'*, *e'* on which the ends are bevelled to secure the desired fit are shown. The upper and lower bevels accurately fit into a bevel formed on the opening in the pulley stile and the pocket cover is fixed in position by means of screws.

7. Construction for Brick or Stone Wall.—In Fig. 3 is shown a perspective view of a section through a **box-frame window** suitable for a stone or brick wall. The various parts are lettered exactly as in Figs. 1 and 2. In brick walls, it is customary to set the window frames during the erection of the walls, thus facilitating the plumbing of the brick jambs, particular care being taken to brace the frames in order to keep them plumb and level.

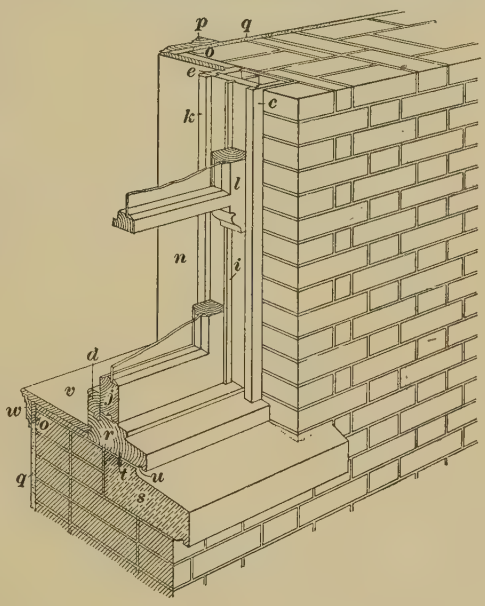


Fig. 3

In stone walls, window frames are not usually set until the building is roofed and is either prepared for the plastering or has the plastering completed. The principal reason for this is the difficulty experienced in setting jamb stones and lintels while the frame is in position ; another is that, with all due care, the frames are more or less damaged during building operations and are never so true to line, level, and plumb as those set in place after the walls are completed. When set after the walls are completed, it is necessary to encase the masonry openings with screeds, or wooden strips, carefully alined and plumbed and so arranged as to allow for a bed of haired mortar $\frac{1}{4}$ inch thick

round the jambs and window head. The frames are secured by means of holdfasts, or wall plugs.

8. **Mullions.**—A mullion is simply a division placed between two sashes. With sliding sashes, the mullion must contain the weight box, but with hinged sashes it need be no more than a bar against which the sashes may close or on which they may be hinged. The former kind is illustrated in Fig. 4, which shows a horizontal section through the mullion *a* in Fig. 10. Inasmuch as the mullion may contain four weights, two for each pair of sashes, instead of two weights, as in the box of a single window, the inside lining *a*, Fig. 4, and the outside lining *c* must be somewhat wider than the same details are in a single frame.

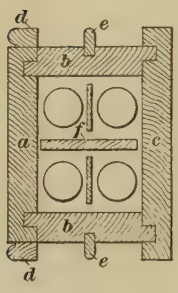


FIG. 4

The pulley stiles *b*, the stop-beads *d*, and the parting strips or beads *e* are detailed in precisely the same manner as in a single frame. In the best work, a parting slip *f* is placed between the two sets of weights, so as to prevent them knocking against one another and becoming fixed in the box ; when this occurs, a pocket in the pulley stile must be placed on each side of the mullion, but where this does not occur, the pocket in the pulley stile may exist on one side of the mullion only, as access to all four weights can be thereby readily obtained. The sill of the window, however, is not housed into the pulley stile of the mullion, as it is with the frame shown in Fig. 8 ; instead, the sill and the window head each extend as one piece across both openings, and each is grooved to receive the mullion pulley stiles. A division between two sashes similar to a mullion, but running horizontally, is called a *transom*.

9. **Triple Windows.**—Considerable difficulty is sometimes experienced in providing a means for controlling the movable sashes of a **triple window** having two stationary side sashes, a double-hung centre window, and mullions as narrow, for instance, as $2\frac{1}{4}$ inches, as shown in Fig. 5. There are several ways of overcoming this difficulty, however. The easiest method is to use spring sash balances, the mortises for which should not be

deep enough to cut through the mullions ; but as these appliances are rather expensive and not always satisfactory, the sashes may be hung with pulleys and weights, as shown in the figure. In (*a*) is shown an outside view of the upper part of such a window, while in (*b*) is shown the working system, which needs no explanation. Clean, neat holes for the sash cords should be bored into

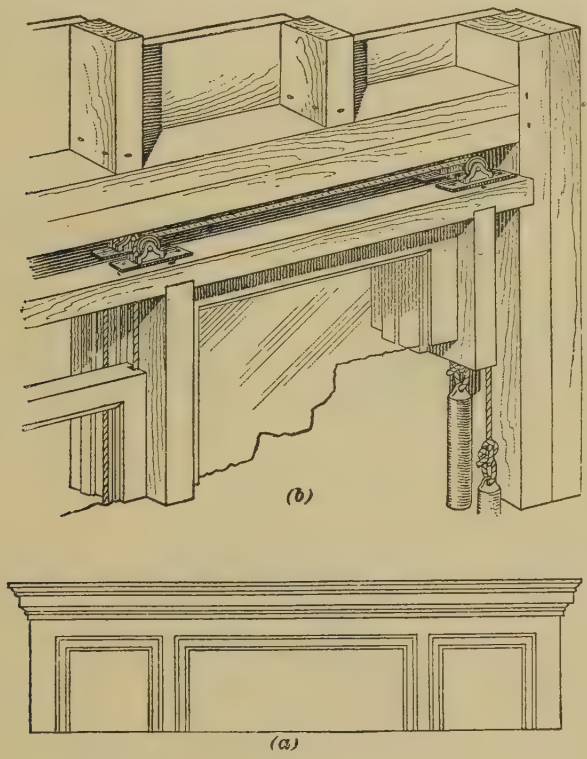


Fig. 5

the yoke, and ordinary pulleys, over which the cords pass to the weight boxes at the sides of the entire frame, are screwed face downwards over them. A wider space than usual, about $2\frac{1}{4}$ inches, should be left between the yoke and the framing, and the inside lining over this pocket should be fastened with screws, so that the pulleys can be reached in case they get out of order.

10. Window Glass.—Sheet and plate glass can be obtained in any size up to 26 feet superficial for sheet, and 100 feet superficial for plate. Glazing usually forms a separate contract from joinery, except in small buildings, and is fully described in *Glass and Glazing*.

11. Sashes.—In construction, sashes vary slightly, according to the manner in which they are hung and the character of the building for which they are intended. Sashes of ordinary dimensions are from $1\frac{3}{4}$ to $2\frac{1}{4}$ inches in thickness, with the bottom rail $3\frac{1}{2}$ to 4 inches in width, while the stiles and top rail are 2 inches

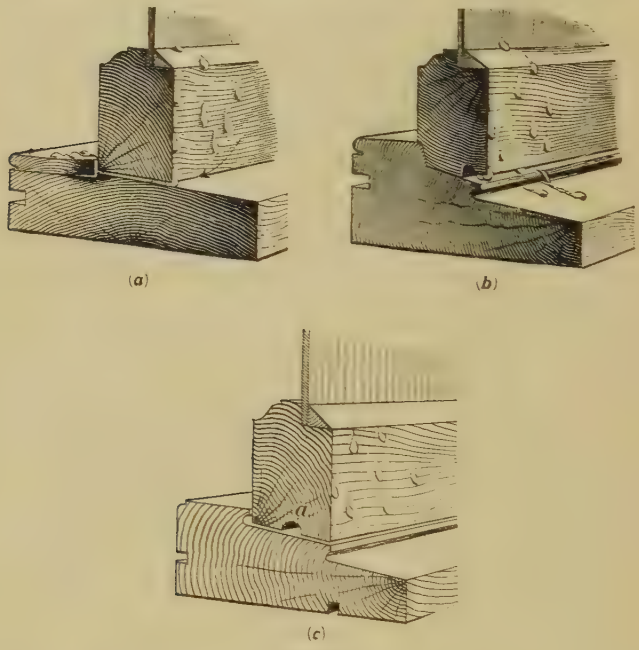


FIG. 6

in width. The meeting rails of double-hung sashes are usually $1\frac{3}{8}$ inches wide, and are bevelled, or rabbeted, to ensure a tight joint. Sashes that are to be glazed with heavy plate glass should be at least 2 inches thick, and should have a bottom rail 4 or 5 inches wide.

12. Water-Tight Sash. — Unless properly constructed and kept thoroughly well painted, the edge of the lower sash of all windows suffers from the action of capillarity. Where a film of water is allowed to form between the sill of the window frame and sash, as shown in Fig. 6 (*a*), it readily follows the vertical grain of the stiles; also the action of the wind will keep packing the rain drops until the inner sill is wet. This may be prevented by forming a groove on the sill of the window frame and on the lower edge of the sash, as shown in Fig. 6 (*b*). Sometimes, as an extra precaution, a double groove is made in the wood sill, as shown in Fig. 6 (*c*), and the lower rail of the sash is grooved on the under side, as shown at *a*. For very exposed situations a metal strip is sometimes fixed on the face of the lower sash, and projects over the joint between the lower edge of the sash and the sill, thus preventing water from blowing in between the two.

13. Sash Making.—Like all framed work in joinery, **sash making** is preceded by the preparation of a measuring rod, on which are set out the various dimensions. Fig. 7 shows a pair of sashes for a double-hung window, the panes of glass of which are to be 10 inches by 8 inches. A rod of proper length, as shown in (*a*), is first prepared as follows: On one side of the central dividing line is set off the distance *a e*, equal to the width of the bottom rail, which in this case is $3\frac{1}{2}$ inches. From *e* to *f* is set off $\frac{3}{16}$ inch for the rabbet, and from *f* to *i* is measured $10\frac{1}{16}$ inches for glass, allowing $\frac{1}{32}$ inch on each edge between glass and wood for clearance; *i h* is then set off $\frac{3}{16}$ inch for rabbet, and *i j* is set off $\frac{1}{2}$ inch for the tongue of the astragal; *k j* is then made $\frac{3}{16}$ inch for rabbet, and *j m* is set off $10\frac{1}{16}$ inches for glass. The $\frac{3}{16}$-inch rabbet is again set off from *m* to *l*, and *l o* is made $1\frac{1}{2}$ inches for the meeting rail. The upper sash is then set out in the same way: a rabbet of $\frac{3}{16}$ inch at *o n*, an opening for glass of $10\frac{1}{16}$ inches at *n r*, another $\frac{3}{16}$-inch rabbet *r p*, a $\frac{1}{2}$-inch tongue *r s*, a rabbet *t s*, a light *s v*, and a top rabbet *v u*; *u b* is then made 2 inches for the width of the top rail. The top and bottom rails are tenoned into the stiles, and *a g* and *b w* are set out on the rod for a relish.

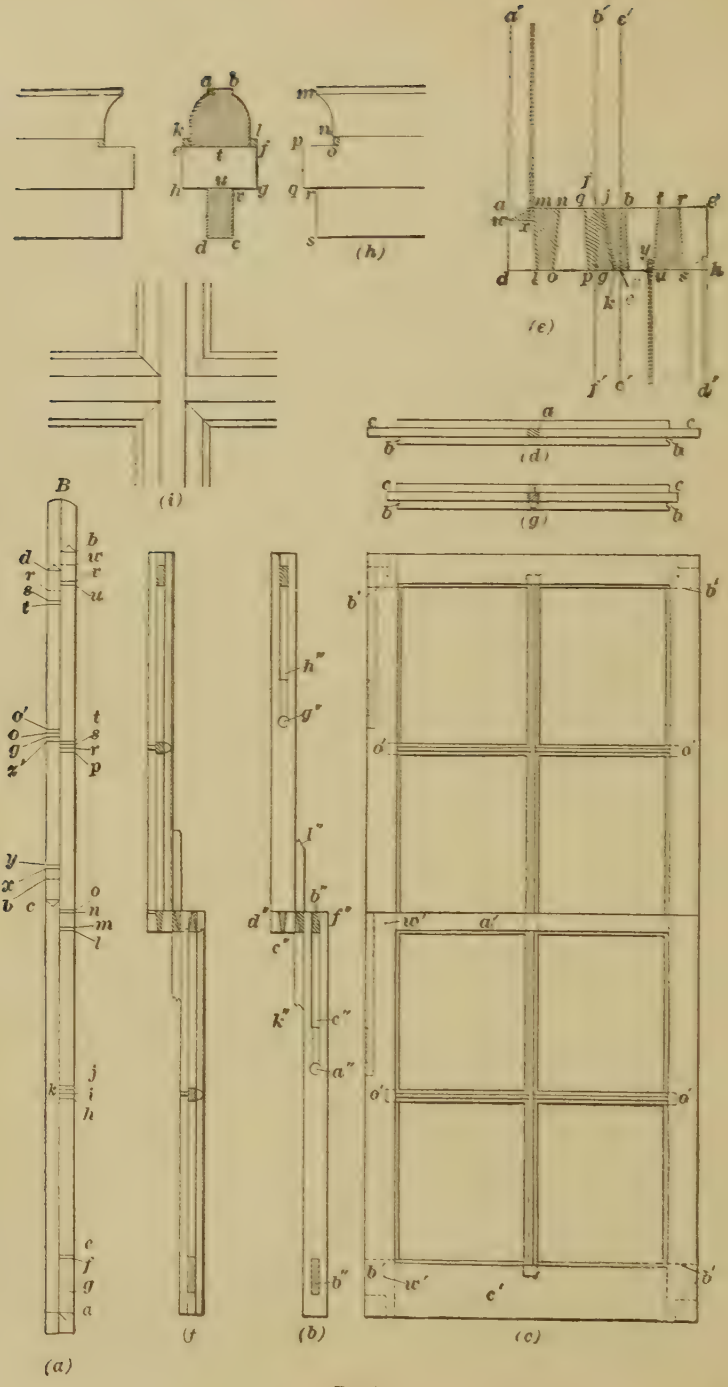


FIG. 7

On the other side of the bar, from *c* to *d*, the divisions of the width are set off in the same manner ; *d t* and *c y* are each made 2 inches for the width of the stiles, *t s* and *y x* are then set off for rabbet, and *t r* and *y b* are each made $\frac{1}{2}$ inch for the length of the tenon on the astragals ; *s o* and *x g* are then made $8\frac{1}{16}$ inches for glass, and the tongue *o g* is made $\frac{1}{2}$ inch. At *o' o* and *g z'* is shown the width of the rabbet on each side of the astragal.

14. In Fig. 7 (*b*) is shown the side elevation, at (*f*) a sectional elevation, and at (*c*) the interior elevation of the two sashes in their relative positions. The upper and lower rails *a'* and *c'* are tenoned into a mortise in each stile, as shown dotted at *b'*, and are secured by means of $\frac{5}{16}$-inch pins *w'*. The tenons extend through the stiles, and may be seen on the side of the sash shown at *b''*. The astragal bars are also tenoned into a mortise sunk into each stile, but extend only $\frac{1}{2}$ inch into the wood, as shown at *o'*. The meeting rails are dovetailed to the stiles, as shown at *f'' d''* in the side elevation (*b*), and the vertical astragals are mortised into the top and bottom rails, and are themselves mortised to receive the tenons of the cross-bars.

In Fig. 7 (*d*) is shown the top edge of the lower rail, in the centre of which is sunk the mortise *a* for the astragal bars ; on the ends are shown the tenons *c*, which are to fit the mortises in the stiles. The moulding on the inside of the rail is not mitred in the angle, but is scribed over the stile moulding, as shown at *b*.

15. In Fig. 7 (*e*) is shown a section through the meeting rails, which illustrates the method of cutting the dovetails on the stiles to ensure a satisfactory joint. The two meeting rails are first planed down to a section of about $2\frac{1}{4}$ inches by $1\frac{1}{4}$ inches. This would cause them to occupy the positions shown at *a b c d* and *e f g h*, but they are afterwards bevelled off on the line *j k*, as explained hereafter. The lower ends of the stiles of the upper sash and the upper ends of the stiles of the lower sash are then dovetailed, as shown at *a d l m* and *n o p q* and at *s r e h* and *v b t u*. The dovetail pins *l m n o* and *u t r s* are then cut on the meeting rails, and ensure a joint that will be unlikely to work

loose or shrink out of place after the sashes are hung. On the outside of the lower rail of the upper sash, a rabbet *w x m* is cut to receive the glass, and on the under side of the upper rail of the lower sash a groove *u y* is ploughed to receive the upper edge of the glass in this lower sash.

The thickness of the stiles of the sash is only $1\frac{3}{4}$ inches from *a′* to *b′* or from *c′* to *d′*, while the meeting rail extends nearly $\frac{1}{2}$ inch beyond this, or close to the edge of the parting strip *b′ f′ c′ e′*. When the sashes are hung, the edge of each meeting rail is planed off to the line *j k*. Thus, when the sashes are closed in the position shown in the illustration, the bevelled edges will act as a wedge, and by ensuring a tight joint will tend to prevent the sashes from rattling. The bevelled edges are sometimes rabbeted or checked; this makes the window more burglar proof, as, with the check, it is impossible to insert a knife or other instrument, between the sashes, to open the sash fastener.

16. In Fig. 7 (*g*) is shown a plan of one of the horizontal bars mortised into a vertical one, thus dividing the sash into four parts. At *c* is shown the projection of the tenon that enters the mortise in the side of the sash, while the moulding on the sash bar is cut out to scribe over the moulding on the stile, as shown at *b*. The vertical bar is also similarly scribed and mortised into the top and bottom rails of each sash, while at its centre a mortise is cut through the material to receive the tenons on the middle ends of the horizontal sash bars.

This is more clearly shown in (*h*), where *a b c d* is a section through the vertical bar at the centre of the joint. At *e f g h* is shown the portion that is cut through to receive the tenons of the sash bar, and at *e k* and *f l* are shown the mitred edges of the upper portion of the square section of the bar. These parts are so joined as to present a neat appearance, as well as to ensure a perfect joint. The upper part of the bar *m n* is cut out to scribe over the moulded part of the bar at *b l*, and the tenon *o p q r* is inserted in the mortise *f e g h*, but extends only half-way through it, or to the centre line *t u*, leaving the other half of the mortise *e t u h* for the tenon on the other half of the horizontal bar. The portion *r s* then butts against the rib at *v c*, and the

whole is secured in place by the pressure of the stiles of the sash against the outer ends of the horizontal bars. Mortising the horizontal bars into the stiles is effected in precisely the same manner as mortising into the vertical bar, the moulded portion being scribed and the solid central part let into the mortise.

17. At *a''* in the side elevation, Fig. 7 (*b*), is shown a round hole $\frac{7}{8}$ inch in diameter and $\frac{3}{4}$ inch deep. A hole like this is bored into the sides of each sash just above the middle, so as to receive the knot of the sash cord that is to extend over the pulleys to the balance weights in the weight box. A groove $\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch deep at *c'' b''* and extending from the top of the sash to *c''* is cut for the cord to lie in ; and a hole $\frac{3}{8}$ inch in diameter, bored from *c''* to the $\frac{7}{8}$-inch hole at *a''*, as shown by the dotted lines *c'' a''*, holds the cord in place and prevents the knot from slipping out of the hole at *a''*. At *k'' l''* is shown a portion of the parting bead in its position relative to the sashes. It shows that, as the meeting rails of the sashes extend beyond the interior and exterior faces of the upper and lower sashes, respectively, the bevelled portion of these rails must be notched out on the ends to fit round the parting bead.

18. When all the parts of a sash are made, stiles, rails, vertical and horizontal bars, the whole frame is drawn together with bench clamps, and wedges dipped in glue are driven in on each side of the tenons *b'*, Fig. 7 (*c*). The mortises are made $\frac{1}{2}$ inch wider on the outside than on the inside of the stiles, to make room for the wedges, which are driven until the joint is closed tight. Holes $\frac{1}{4}$ inch in diameter are now bored through each mortise and tenon *b'* and each dovetail joint, and wooden dowels dipped in glue are driven through the joint to secure it, as shown at *w'*. Barbed steel or iron pegs are often used instead of wooden dowels. When the clamps are removed, the faces are smoothed and made ready for fitting into the frames.

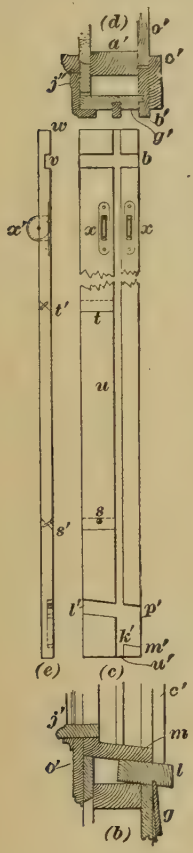
19. Fitting and Hanging Sashes.—To fit and hang the sash in the window frame, it is necessary to remove the stop-bead and parting strip and then fit the upper sash so that it slides easily between the pulley stiles. The parting strip is then replaced,

and the sash secured in place by nailing a couple of wooden blocks under it. The lower sash is then similarly fitted, the lower rail of the sash being planed off until the meeting rails rest snugly together, as required. In providing weights for the sashes, the pair for the upper sash must be at least $\frac{1}{2}$ pound heavier than the weight of the sash, while for the lower sash the weights must be at least $\frac{1}{2}$ pound less than the weight of the sash. This $\frac{1}{2}$-pound excess in the upper weights and in the lower sash tends to keep the sashes close and tight against the window head and the sill.

20. To hang the sash, the pockets must be opened by unscrewing and removing the covers. The sash cords are carried over the pulleys by means of some light but strong string. This string is forced over the pulley and within the box by means of a lead weight, called a *mouse*, which is small enough to go over the pulley sheave, but heavy enough to carry the string. The sash cord is then made fast to the weight and, with the top sash resting equally on the sill, the weight is pulled up to the pulley; the cord is then cut off just long enough to permit a knot to be tied at the required point. When both weights for the upper sash are attached, the sash is removed from the frame far enough to permit the cord to be pushed down through the groove and the hole shown at g'' h'', Fig. 7 (*b*), and a knot is tied to prevent it from pulling out. When metallic-cord grips are used, knots on the ends of the sash cord are not required, but care should be taken to have the grip of a size to properly fit the cord. When both weights and both cords are thus attached, the sash is replaced in the frame and pushed up and down a few times to test its efficiency. The lower sash is then hung in a similar manner. When both sashes are hung and are found to slide satisfactorily, the stop-bead is replaced and secured, and the pocket is closed and screwed up tight to prevent the cover from catching on the lower sash.

21. Sash Window for Frame Dwellings.—Although wooden-framed buildings are not much used in the British Isles, they are very common in the Colonies and America, so that information concerning the fitting of sash windows in such structures may be useful. In Fig. 8 is shown a window frame for an ordinary

frame dwelling; the various parts are as follows: In (*a*) is shown a section through one side of the frame. The stud at the side of the opening is shown at *a*, the exterior sheathing or boarding at *b*, the lath and plaster on the interior at *e*, the pulley stile at *g*, and the sash weights at *i*. At *f* is shown the exterior sash stop, against which is secured the exterior casing, or shutter stile, *c*, which must be of the same thickness as the shutter. The exterior sheathing *b* is cut flush with the inside of the stud opening. The casing *c* is secured to the stud *a*, through the sheathing *b*, thereby keeping the pulley stile in its place on the outside, while the architrave, or interior casing, *j* performs the same function on the other side of the wall. The pulley stile *g* is ploughed for the parting strip *h*, which forms a channel for the upper sash to slide in. The lower sash is hung on the inside of this parting strip, and is secured in place by a stop-bead *n*. The stop-bead and parting strip are secured in place on the pulley stile by nails or screws, but either may be readily removed and the sash taken out at any time it is desired. The parting strip may be kept in place simply by the tightness of its fit in the groove in the stile, but the stop-bead should be screwed to the pulley stile.



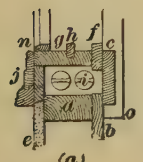


FIG. 8

22. In Fig. 8 (*b*) is shown a vertical section of the frame through the sill and other details of the lower part of the window. The sill *m* is inclined at a pitch of about $1\frac{1}{2}$ inches to the foot, and its outer edge rests on the sub-sill *l*, which is inclined at a similar angle and has its under side grooved to receive the upper edge of the clap-boards *g* or shingles covering the side of the house. At *o'* is

shown the inside casing, or *apron*, as it is frequently termed, which is attached to the back of the sill *m* and which, with the sill cap, forms the inside finish of the lower part of the window. The inside casing, or architrave, *j'*, as shown at *j*, view (*a*), rests on the sill cap shown over the apron *o'*. The sub-sill *l* receives the bottom of the window frame on the outside of the house; on it rests the exterior casing *c'*, which is seen in the sectional plan at *c*, and which frames the window opening on the outside in the same manner as does the architrave *j'* on the inside. Both the sill and the sill cap are carried beyond the casings *c* and *j*, and are returned against the walls, as shown at *o* in view (*a*).

23. In Fig. 8 (*c*) is shown the elevation of the inside face of one of the pulley stiles. The lower part of the pulley stile *l' m'* is cut out to receive the ends of the sill and sub-sill, the sill extending through the entire thickness of the stile from *l'* to *p'*, and the sub-sill extending from *k'* about 2 inches beyond the face of the stile at *m'*. The $\frac{1}{2}'' \times \frac{1}{2}''$ groove ploughed to receive the parting strip is shown at *u*. The depth of the cut-out portion *l' p' m' k'* is equal to the depth of the groove *u*, and, as shown at *u'*, the groove extends to the bottom of the stile. The upper part of the pulley stile is grooved at *b* to receive the window head, immediately below which are placed the two pulleys *x*, *x*, one for each sash. These pulleys are let into the face of the stile, so that the face plates are flush with the inside of the frame, but the wheels extend through to the interior, as shown at *x'*, in the side elevation (*e*) of the stile. The depth of the groove to receive the window head is $\frac{1}{2}$ inch, as shown at *v*; the material from *v* to *w* extends 2 inches above the window head, to permit the fitting of the frame to the stud opening.

At *s t* in the elevation (*c*) is shown the pocket or opening to the weight box. This opening is cut out, as previously described, to permit easy access to the weights. In the elevation of the pulley stile at (*e*), the pocket cover is shown at *s' t'*, as well as the lines on which the ends are bevelled to secure the desired fit. The upper bevel at *t'* is notched over the shank and under

the head of the screw inserted in the back of the stile, as shown at t'. The lower bevel s' is then secured against the bevel of the pocket by means of a screw driven straight through the face of the cover, as shown at s in the elevation (c).

24. In Fig. 8 (d) is shown a section through the window head at the centre of the opening. Here, the stud a' is shown in its position at the top of the frame opening, while the window head g' is shown 2 inches below ; these 2 inches permit projections of the stiles, shown in (e) at v w, to be fitted to the top of the opening. The inside architrave j'' is then secured across the opening between the stile g' and the stud a', and the outside facing c' is laid over the exterior casing b' and extends to the sheathing at

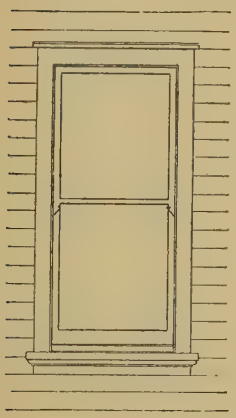


Fig. 9

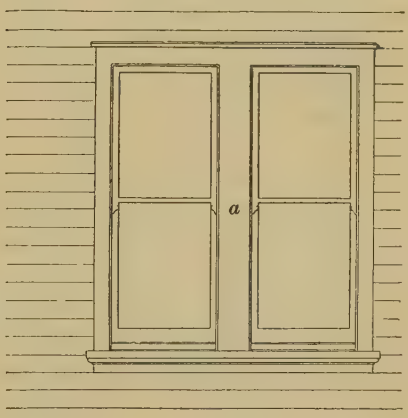


Fig. 10

the edge of the framed opening at o'. A cap member should be placed over the upper edge of the outside casing to throw off the water, or a cap flashing of lead or zinc may be turned up 2 inches under the siding, lapped over, and turned down an inch on the face of the casing, with the lower edge securely nailed.

This practically completes the description of the parts of the frame for any single window in a frame building such as shown in Fig. 9 ; when, however, windows are coupled in pairs or triplets, a mullion a, Fig. 10, must be included in the frame.

25. Construction for Wood Wall.—In Fig. 11 is shown a view of a window frame with sliding sash, adapted for a frame building.

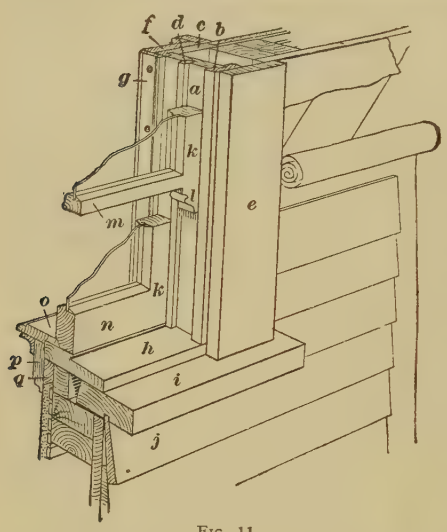


FIG. 11

The pulley stile *a* may be from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches thick, and should be, though not always, tongued into the exterior casing *b* and the inside casing *c*, each of which is $\frac{7}{8}$ inch thick. These tongues make the stiles rigid and prevent them from deflecting sidewise when the sashes are being operated. An open space of from 2 to $2\frac{1}{2}$ inches is left between the back of the pulley stile and the rough stud, thus forming a box for the weights. A movable pocket for the insertion of the weights is cut out of the lower portion of each pulley stile on the inside, so that it may be covered by the lower sash. The parting strip *d* is $\frac{1}{2}$ or $\frac{5}{8}$ inch thick, and passes into a groove $\frac{3}{8}$ to $\frac{1}{2}$ inch deep in the pulley stile. The outside casing *e*, 5 inches wide by $1\frac{1}{8}$ inches thick, is firmly nailed through the $\frac{7}{8}$-inch exterior casing into the pulley stile and to the $\frac{7}{8}$-inch wall sheathing. The inner face of the window frame is finished with a casing *f*, which may be of any style of finish, in this case by an architrave, the width being sufficient to cover the plaster joint. The sash stop *g*, from $\frac{1}{2}$ to $\frac{5}{8}$ inch thick, is secured with round-headed screws passing through slotted sockets for adjustment. The members *g*, *d*, and *b* should be kept in line, their projection beyond the face of the pulley stile being regulated by the thickness of the sash top.

26. The sill *h*, from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches thick, is tongued into the pulley stiles and well nailed. Sills are sometimes made with a straight inclined surface instead of being worked with two fascias,

as shown. When water collects on the sill, it is readily drawn under the lower rail *n* of the sash by capillarity, or it may be driven in by wind ; by raising the surface under the sash above the level of the outer portion, and running a small rounded groove in the fillet, the effect of the wind is to divert the water outwards. Under *h* is placed the sub-sill *i*, $1\frac{7}{8}$ inches thick, which is attached to the pulley stile and likewise grooved for the reception of the bevelled siding *j*.

27. For durable work, the window frames should be put together with stiff white-lead paint, particularly adjacent to the sill and sub-sill. The sashes *k* are made from $1\frac{3}{8}$ to $1\frac{7}{8}$ inches thick. Strength is added to the upper sash by the elongation of the stile, forming a moulded horn *l*, as by this device the tenon of the meeting rail *m* can be made to equal its thickness. The meeting rails, $1\frac{3}{8}$ to $1\frac{7}{8}$ inches thick, according to width of opening, may be double- or single-bevelled, as shown, so that they will come tightly together when closed. The lower rail *n* may be from 3 to $4\frac{1}{2}$ inches wide, and should be accurately fitted to the sill ; the outer edge should be clear about $\frac{1}{8}$ inch, but the inner portion should be in contact with the sill, thus preventing the ready passage of water. The inner face should be rabbeted and bevelled to fit the edge of the stool *o*. The stool should be rabbeted to form an air-tight joint and should be bedded in white lead. An apron *p* is fixed to the edge of the sill and a plaster ground *q*, and is finished with a bed mould as shown. The length of the apron should be equal to the width from out to out of casings, and have the mouldings returned on same.

CASEMENT WINDOWS

28. Instead of being hung or balanced, window sashes may have hinges fixed at the side, top, or bottom, or they may be hung on pivots ; all windows so hung are termed **casement sashes.** Sometimes those hung at the sides are hung in pairs, closing at the centre with rabbeted meeting stiles in much the same way as a pair of folding doors. Casement sashes are often used in positions where they would more correctly be described

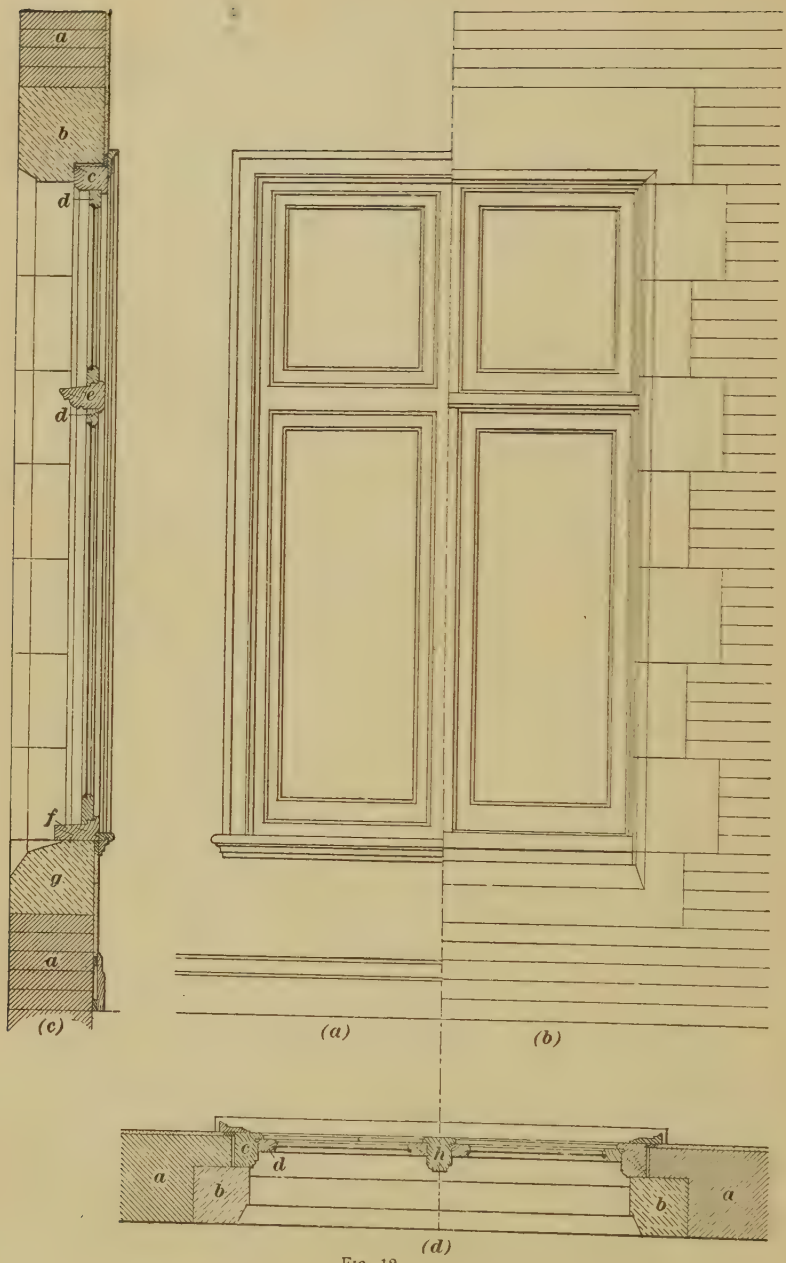


Fig. 12

as doors than windows, so that when a casement window runs down to the floor level, and is constructed in two leaves with a rabbeted or other form of meeting stile, giving access from a room to the garden, or on to a balcony or veranda, it is called a **French casement.**

29. Casement Window in Brick Wall.—In Fig. 12 (*a*) is shown half the interior elevation of a casement window hung at the sides; in (*b*) is shown half the exterior elevation of the same window, showing stone dressings to the jambs; and in (*c*) is shown the section through the centre of the window. Here, *a* is a $13\frac{1}{2}$-inch brick wall; *b*, the stone head of the window; *c*, the frame to which is hung the sash *d*; a transom *e* divides the upper and lower sashes. The wood sill *f* rests on the stone sill *g*, which is bedded on the brick wall. In the plan (*d*), *b* is the stone facing of the wall *a*, and *c* is the frame, with the sash *d* and the mullion *h*.

The stone sill is shown flush with the face of the brickwork and not projecting beyond it to drip the water off. This is not good practice, as the water runs down the face of the wall, making it damp and leaving unsightly stains on the face of the work.

30. Casements Opening Outwards.—In Fig. 13 (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*) are shown several details in plan of the finishings to a casement sash. In (*a*) is shown the plan of the window drawn to a larger scale than in Fig. 12. The brick wall is shown at *a*, the stone jamb at *b*, and the casement frame at *c*. This frame is usually made about $4\frac{1}{2}$ inches by 3 inches, or 5 inches by 4 inches, rabbeted as shown, to form a stop for the sash *d*. It is shown to be moulded on the outside, which gives a very good appearance. It is fixed in the brickwork flush with the face of the internal plastering *j*. Next to the frame is fixed a rough ground *l* similar to those fixed next to door frames; to this is fixed the moulded architrave *g*, which effectively covers the joint between the plaster and the wood frame. The sash *d* has a projection *i* on its edge, which, when the window is shut, fits into the groove in the frame. This method of construction forms a very effective means of keeping the wet and draught

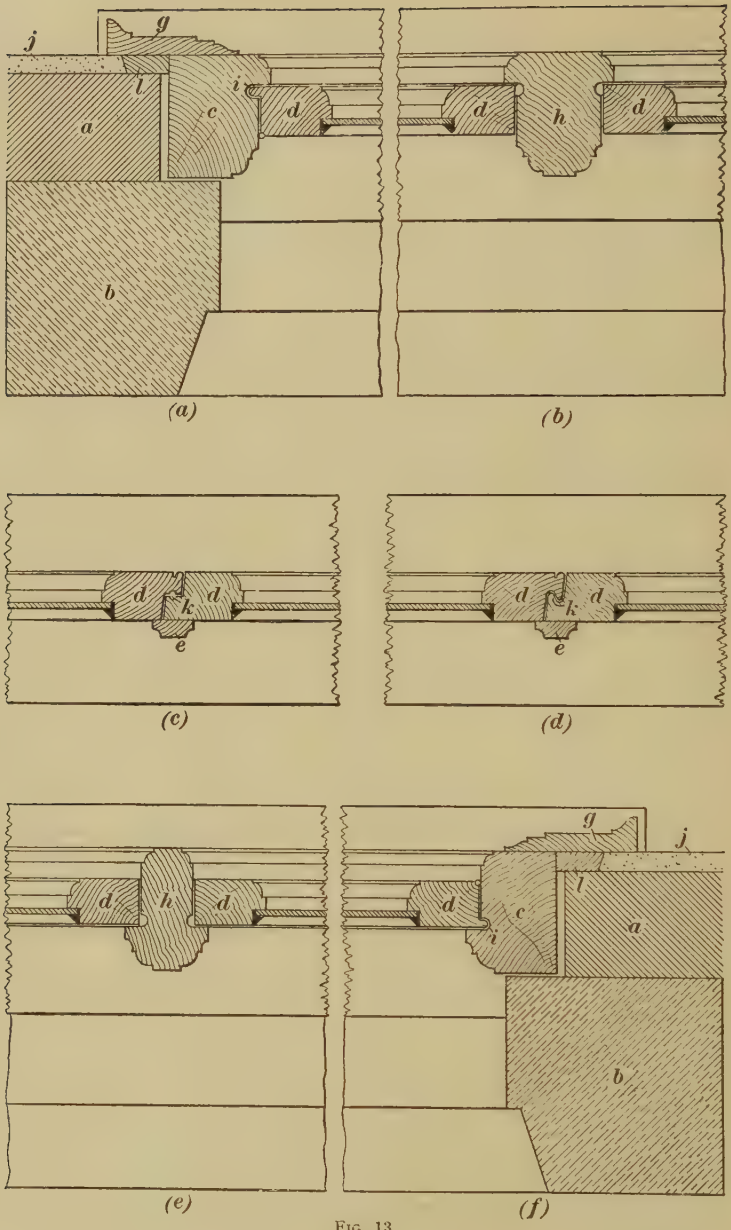


Fig. 13

from getting into the room. The sash *d* of a casement window is formed similar to that of a hung sash and is of about the same dimensions.

31. Mullions.—Fig. 13 (*b*) shows a detail of the mullion *h* to a casement window. This is generally made the same size as the frame, but is rabbeted on each side to take the two sashes *d*, *d* as shown. A slightly different method of construction is shown here, as the sashes *d* are made square on their edges and a groove is made as shown in the mullion. The object of this groove is to prevent wet from obtaining access to the inside of the window. The edge of the sash *d* being flush with the side of the mullion *h*, wet may be drawn up between the two by capillary attraction ; but when it is drawn as far as the groove, it can get no farther, but runs down the groove on to the sill, and gets away to the outside again.

32. Meeting Stiles.—Fig. 13 (*c*) shows one method of constructing the meeting stiles of two sashes when they are hung in pairs, without a mullion between them. This construction is very similar to that shown for folding doors, but to guard against the danger of water penetrating the window, and also against draughts, a cover moulding *e* is fixed to one of the sashes to cover the joint. As a second precaution, and in case any wet should find its way past or behind this cover moulding, a groove is made on the inside of the rabbeted meeting stiles, as shown at *k*. The meeting stiles between casements are sometimes made as shown in (*d*), in which case they are said to be **hook rabbeted.**

33. Casements Opening Inwards.—Fig. 13 (*e*) and (*f*) show the details of a mullion and frame for a casement opening inwards. In (*e*), the mullion *h* is of similar construction to that shown in (*b*) ; the sashes are shown at *d*. In (*f*) are shown the frame *c*, the sash *d*, the $13\frac{1}{2}$-inch brick wall *a*, the stone jamb *b*, the plaster *j* on the inside of the wall, the rough ground *l*, and the architrave *g*. Casements opening inwards are not to be recommended, as trouble is always experienced when they knock against curtains and blinds fixed on the inside of the room, and they are very

difficult to make water- and draught-proof. A joint is shown in Fig. 13 (*f*) at *i* which is similar to that shown at *i* in (*a*).

34. Head and Transom.—In Fig. 14 (*a*) is shown a section through the casement window to a larger scale than that shown in Fig. 12. Here *b* is the stone head and *c* the wooden frame to which the casement sash *d* is hung. The sash is shown hung at the top and opening outwards. The transom *e* is about 7 inches deep by 9 inches or 10 inches wide, according to the detail of the moulding desired on the front edge. Of course, if desired, it can be the same size as the frame and left square on the face without a moulding. The transom is shown double rabbeted, to prevent, as far as possible, wet driving through; the under side of the sash *d* is rabbeted and throated for the same reason. The upper edge of the transom should be sloped or weathered, as shown at *h*, to shed the water, and a drip *i* should be formed in the moulding, so that the water may drip off and not run down the face of the window.

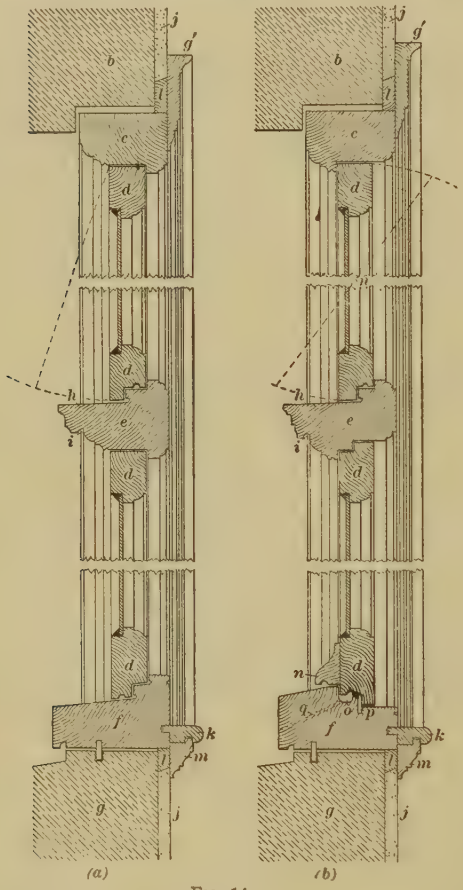
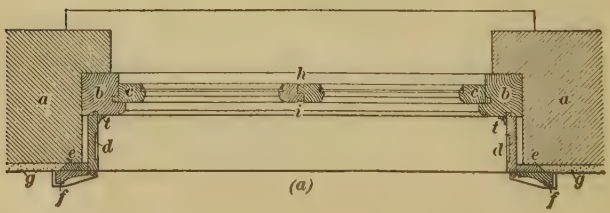


FIG. 14

35. Sill.—At *f*, Fig. 14 (*a*), is shown the sill of the window, which is constructed like that for a balanced sash. It is bedded on the stone sill *g* and has a water bar to break the joint. In this case it is double rabbeted ; the lower rail of the sash *d* also is rabbeted to close against it. The sash below the transom *e* and closing against the sill *f* is intended to be hung at the sides. At *k* is shown the window board, with the moulding *m* under it and grooved into it, and fixed to the rough ground *l* which forms a stop to the plaster *j* ; while at *g'* is shown the architrave stopped against and fixed to the frame *c* and the rough ground *l*, which forms a stop to the plaster *j*.

36. Casements Hung on Centres.—In Fig. 14 (*b*) is shown, in detail, a section through a casement window. The sash between the head *c* and the transom *e* is hung on centres and opens as shown by the dotted lines, turning about the centre *n*.

37. Sill for Casement Opening Inwards. — In Fig. 14 (*b*) is shown a detail through the sill of a casement that is to open inwards. As it is difficult to make a casement sash that opens inwards water-tight, extra precautions must be taken to keep out the wet. At *f* is shown the wooden sill against which the casement sash *d* shuts. This sash is rabbeted on the under side, and the rabbet is grooved. On the outside of the lower rail of the sash is fixed a moulding *n*, which has a throat or groove on its under side, so that any water running down the face of the casement glass may be dripped off on to the sill *f* and be carried away. A groove *o* is formed in the sill to catch all water that may be blown beneath the lower rail of the sash *d* ; and as an extra precaution to prevent this water being blown into the room, a metal water bar *p* is fixed next to this groove. All water blown into this groove passes to the outside by means of holes *q* in the sill, shown by dotted lines, made at intervals of 2 or 3 feet along the length of the sill. The finishings of this sill are similar, in all respects, to those described in (*a*). In situations where the wind is very strong it may blow up through these holes, and force the water into the room. This can be obviated by fixing a metal tube in these holes on the outside of the sill, and making its head in the form of a **T**.



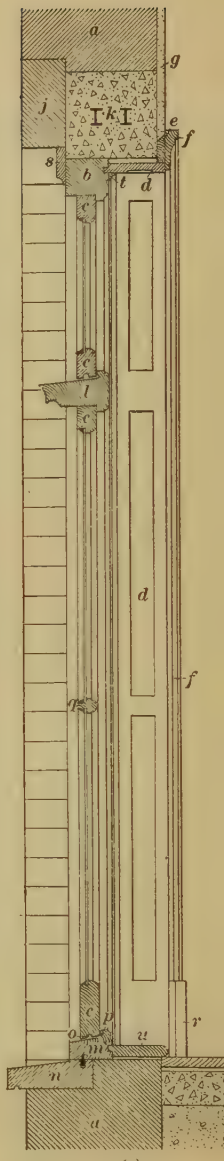


Fig. 15

The stem is inserted in the hole, and water flows down the holes into the stem, finding its way to the outside through both arms of the **T**.

38. French Windows.—Fig. 15 shows the plan (*a*), elevation (*b*), and section (*c*) of a French window. In the plan (*a*) are shown the $13\frac{1}{2}$-inch brick wall *a* and the rabbeted frame *b*, to which are hung the French casements *c*. The construction for a window of this description is very similar to that of ordinary casements before described. The inside lining is shown at *d* with a small cover mould *t* to cover the joint between the lining and the frame, the rough ground at *e*, the architrave moulding at *f*, and the plaster on the inside of the wall at *g*. The architrave is often stopped on a specially shaped block shown at *r* in (*b*) and (*c*), instead of running it down to the floor. The sashes are hung with small hinges, and the meeting stiles are rabbeted in the same manner as folding doors, as shown at *h i*, in (*a*). This is for the purpose of providing a tight joint when they are closed.

39. In the vertical section (*c*), taken through the centre of one of these sashes, the wooden sill is shown at *m* and the stone window sill at the floor level at *n* ; the lower sash rail *c* is grooved on its under side, as shown at *o*. The sill is worked with a rabbet, the front of which is grooved, as shown at *p*, while the top of the sill is bevelled or weathered off to shed the water. The groove in the front of the rabbet *p* tends to prevent water from being blown into the crack during a rainstorm, and the slanting sill and the grooved lower rail permit the moisture to drip off the latter and run to the outside of the opening. At *u* is shown the wooden finish to the inside of the sill against the floor boards.

At *q*, Fig. 15 (*c*), is shown the section of the middle bar of the window, which may also be seen in the elevation at *q'*. At *l* is shown the fixed transom over the hinged sash and the lower rail of the transom sash *c* over it. The hinged sash is only 5 feet 6 inches in height, as this is sufficient to permit the window to be used as a means of ingress and egress, while the full opening is 7 feet high.

40. In the construction of the window head, the framing is precisely similar to that at the sides, shown in the plan (*a*), except that the frame *b* in the top of the window is not grooved as shown in the plan (*a*). The brick arch on the outside of the wall is shown at *j*, and a concrete relieving lintel, reinforced with two small steel joists to take the weight of the wall over the head of the window, is shown at *k*. At *s* is shown the face piece fixed under the arch *j* to cover the joint between the head *b* and the concrete lintel *k*.

WINDOWS IN CURVED WALLS

41. When the wall in which a window frame is to be built is curved, as in a circular tower or a semicircular bay window, the special form of frame necessary is set out from a template of the exact curve it is required to fit. If, in addition, the head of the window is semicircular or semielliptical, the problem is further complicated by the necessary geometrical development of the details. In Fig. 16 is shown the plan of a window opening and its frame built in the curved wall of a tower. The pulley stiles *a*, *a* are set parallel with the axial line *n f* of the opening or line drawn through the centre of the window to the centre from which the curve of the wall in which the window is inserted is struck. The sash may then be easily removed and replaced from the inside of the structure, which could not be done if the stiles were set on radial lines from the centre of the curve. The back lining is set parallel with the pulley stile to form a proper weight box. All other details of construction are precisely similar to those for windows in straight walls, except that, owing to the curvature of the sill and head, the details of the framing do not join at right angles and the semicircular shape of the window head demands special construction.

42. To unfold, or develop, this semicircular window head, proceed as follows: From each end of a line *a a*, drawn from the inside edges of the pulley stiles, erect the perpendiculars *a b*, which will be equivalent to the continuation of the inside faces of the pulley stiles. Above the plan, draw the line *b b* parallel with *a a*. With the point where this line intersects the axial

line $n\,f$ at d as a centre, and with $d\,b$ as a radius, draw the semicircle $b\,f\,b$, which will be the elevation of the inside line of the window head. Now, divide one-half of this semicircle $b\,f\,b$ into

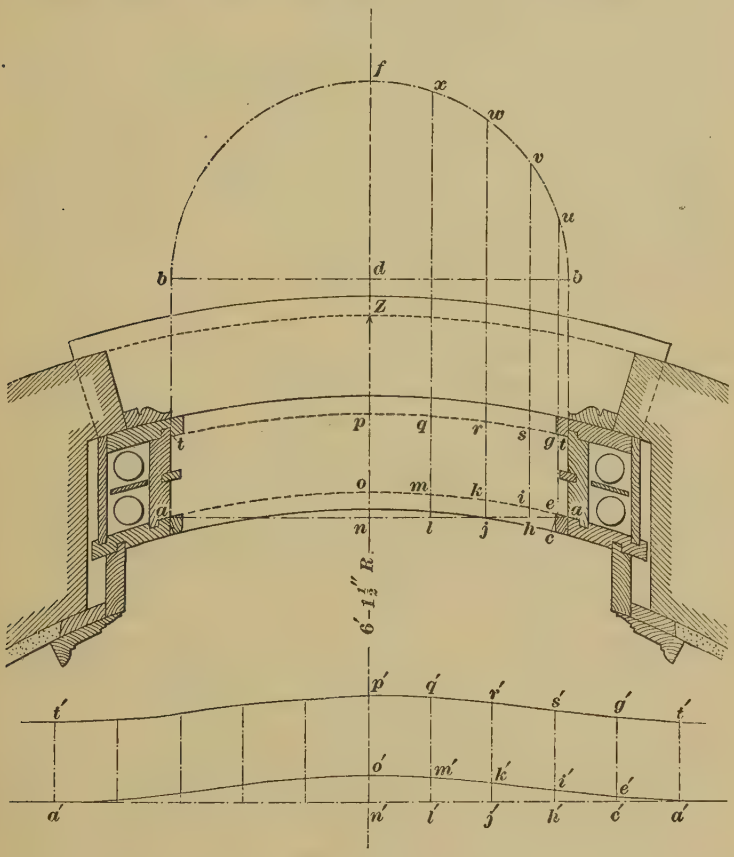


Fig. 16

any number of equal parts by points u, v, w, x, etc., and from these points let fall perpendiculars to $a\,a$, as shown at $x\,l$, $w\,j$, $v\,h$, etc.

Somewhere below the plan, the line $a'\,a'$ is then drawn parallel with $a\,a$. From the centre n' of the line $a'\,a'$ are set off in each direction the lengths $n'\,l'$, $l'\,j'$, $j'\,h'$, etc., each equal to the length of the curved lines $f\,x$, $x\,w$, $w\,v$, etc., and, from the points so

established, perpendiculars to *a' a'*, as *n' p'*, *l' q'*, *j' r'*, *h' s'*, etc., are erected. On these perpendiculars are set off *n' o'* and *n' p'* equal, respectively, to *n o* and *n p*, *l' m'* and *l' q'* equal to *l m* and *l q*, *j' k'* and *j' r'* equal to *j k* and *j r*, etc. These measurements are taken from the plan, where the perpendiculars from the subdivisions of the semicircle *b f b* intersect the curved lines *a o a*, the inside face of the inside lining, and *t p t*, the inside face of the outside lining, shown in the plan of the sill. Curved lines drawn through the points *p'*, *q'*, *r'*, *s'*, *g'*, *t'* and *o'*, *m'*, *k'*, *i'*, *e'*, *a'* will describe the contour of the flat piece required to conform to the shape of the window head when bent round a semicircular form similar to *b f b*. The method of bending this semicircular head has been described.

43. The construction of a sash designed to fit the curved window just described is shown in Fig. 17; the plan is the segment of a circle and the head is a semicircle. As each of the two quarter-circles forming the head has a compound curve, a face mould must be used. To make this mould, draw the line *a b* from the outside edge to the centre of the concave side of the sash, and on the convex side draw a line *c d* parallel with *a b* and tangent to the sash at *u*, until it cuts the line *b b'* at *d*. Draw *d b''* at right angles to *c d* cutting the line *a b* produced at *b''*. Draw *a c* at right angles to *a b*. The rectangle *a b'' d c* then represents the width and length of plank required to get out each piece of the top rail. Divide the curved outside line of the elevation of one-half the window head *a' b'* into any number of equal parts, and from each of these points *g'* draw lines parallel with the centre line *b' e*, intersecting *a b* at *r*, *t*, etc. From these points of intersection draw the lines *b g*, *r j*, *t l*, etc., and the line *d f*, all at right angles to *a b*. Set off on these lines the distances *b d'*, *b g*, *r m*, *r j*, *t m'*, *t l*, etc., equal, respectively, to *o' c'*, *o' b'*, *e' f'*, *e' g'*, etc.; the points *c'*, *f'*, etc., are situated on the inside line of the top rail. Through the points thus established draw the curves *a l f* and *n m' d'*. Then, the curved form *a l g d' m' n* will be the face mould that must be applied to and scribed on the stock from which the half-sash head is to be sawn. The shaded portion at *g f* shows the waste, or surplus, that must be removed in order to

permit the two quadrants to meet in a proper butt joint at *b e*. This surplus is removed on the bevel shown at *d*, which is the

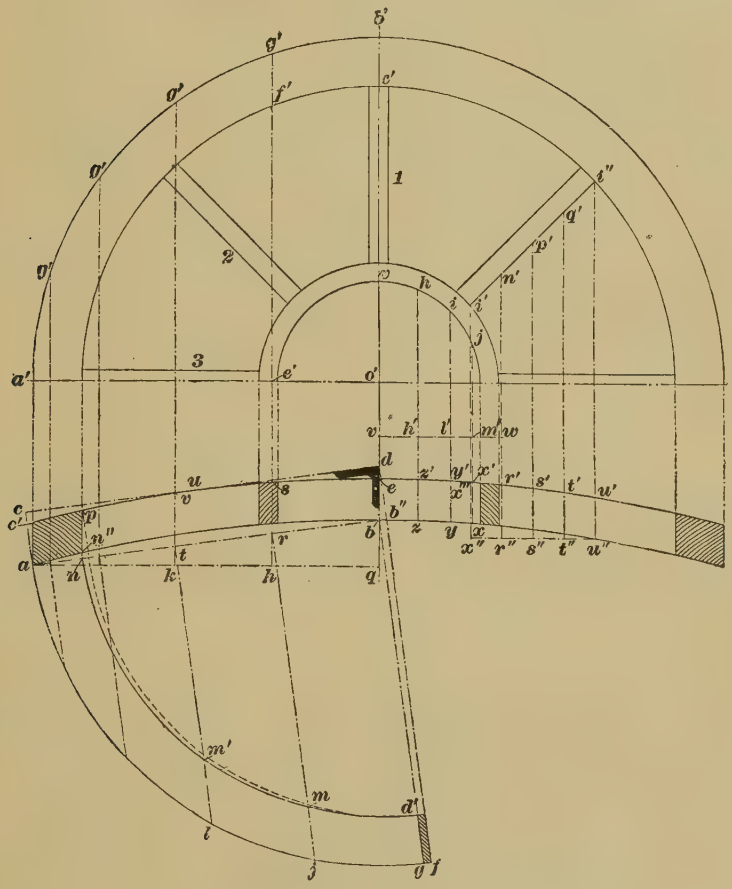


FIG. 17

angle *c d q* formed by the intersection of the tangent line *c d* with the prolongation of the perpendicular centre line *b' b*.

44. The dotted curved line on the concave side of the face mould shows the amount of extra width required, owing to the fact that the head-piece is sawn squarely through the wood. The planks from which the sash head is to be cut is first planed on its

inside edge, to conform with the bevel shown at *d*. The face mould is then set to the edge of this bevel on both sides of the plank and marked, and the surplus wood is cut away to the lines, as marked. The convex and concave edges of the circular head on the plan lines *a c′ e b* and *n″ p e b* will then have the proper shape and angle. The dotted line on the concave edge shows the relative position of the curves *n″ d′* and *p d′* on the inside and outside of the sash in the projected elevation. A perpendicular line drawn from *p* gives the amount of the warp or twist.

45. It is now necessary to make two patterns that may be applied to the finished convex and concave edges of the circular top rail, in order to mark the convex face line of the sash. In

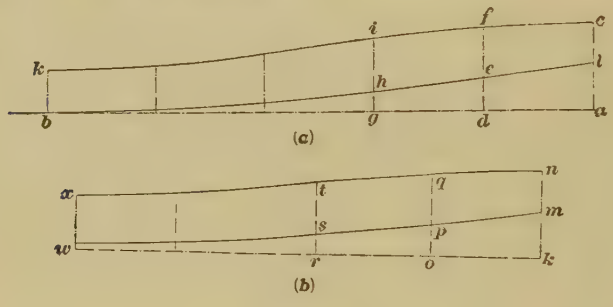


Fig. 18

Fig. 17, continue the centre line *b′ b* to *q* and from *a* draw the line *a q* at right angles to *b′ q*. From the points *r*, *t*, etc., draw lines *r h*, *t k*, etc., at right angles to *a q*. On a straight line *a b*, Fig. 18 (*a*) set off the distances *a d*, *d g*, etc., equal to the divisions *a′ g′*, *g′ g′*, etc., on the convex side of the sash head *a′ b′*, Fig. 17, and from these points erect the perpendiculars *a c*, *d f*, *g i*, etc., equal, respectively, to *q e*, *h s*, *k v*, etc., Fig. 17. Then, through the points *c*, *f*, *i*, etc., Fig. 18 (*a*), draw a curved line, which will be the line required on the convex face of the sash head. Before applying this pattern to the sash head, it is necessary to trace curve *l e h b* that will act as a guide in placing the pattern in position for scribing. To do this, *a l*, *d e*, *g h*, etc., are set off equal to *q b*, *h r*, *k t*, etc., Fig. 17, and the curve *b h e l*, Fig. 18, is drawn through the points so found. The pattern *b h l c i k*

is then cut out, and is bent round the convex edge of the rough-sawn window head *a b d c*, Fig. 17, in such a position that *b h e l* corresponds with the inside line of the plank, as *a t r b* of Fig. 17. The outside curve *k i f c* is then scribed on the sash head, and will conform to the curve required.

46. The other pattern must trace this same curve on the concave side of the sash head. On the line *k w*, Fig. 18 (*b*), are set off the distances *k o*, *o r*, etc., equal to *c' f'*, etc., on the concave side of the window head in Fig. 17, and, on the perpendicular lines raised from these points, the distances *k m*, *k n*, *o p*, *o q*, *r s*, *r t*, etc., are set off equal, respectively, to *q b*, *q e*, *h r*, *h s*, *k t*, *k v*, etc., Fig. 17. The curves traced through the points *n q t x* and *m p s w*, Fig. 18 (*b*), will then form the pattern for the concave side of the window frame. This pattern must be applied in the same manner as the pattern described in Fig. 18 is applied to the outside, the line *m p s w* being made to conform to the straight line *b n* of the concave side of the sash shown in Fig. 17.

47. These patterns may be cut out of either cardboard or thin sheet zinc, so that they may be readily bent to the curved edges of the top rail. The pattern shown in Fig. 18 (*a*) is bent round the outside of the top rail, pressed closely, and temporarily tacked into place, keeping *l c* to the joint and the line *l e h b* to the straight face of the plank marked *a b* on the plan in Fig. 17, the convex face line *c f i k* being then marked on the sash head. The pattern shown in Fig. 18 (*b*) is applied in the same manner to the under, or concave, side of the sash head, keeping the line *m n* to the joint and scribing the curve *n t x* on the outside, or front, edge of the sash. The surplus, or overwood, is then planed off to the convex lines so marked on the sash head, always working the plane in a direction parallel with the joint line *g d'*, Fig. 17. When this is done and the convex face of the frame is finished, the marking gauge is set to the thickness of the sash, and the concave, or inner, face of the sash is gauged from the outside. The overwood is then removed, moving the plane parallel with the joint line *g d'*, and finishing carefully to the scribed lines.

The two quadrants, each representing one-half the sash head, are now dowelled together, as shown at *b* and *b'*, Fig. 19, and

secured with a hand-rail bolt in the centre, as shown at *a* and *a'*. The bolt brings them into close contact, while the dowels in opposite corners *b'* serve to keep the pieces in proper alinement. The pieces are then glued together, and the mouldings are worked.

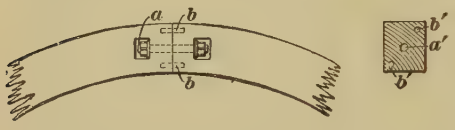


FIG. 19

48. The arch bar may be sawn out of a single piece of plank in the same manner as each half of the window head, or it may be bent in one or more thicknesses of wood, set out from a pattern drawn as follows: The concave side of the arch bar, Fig. 17, is divided into a number of equal parts by points *h*, *i*, *j*, etc., from which perpendiculars are dropped to the plan, intersecting it at *z'*, *z*; *y'*, *y*; *x'*, *x*; etc. At any convenient point above the plan, a horizontal line *v w* is drawn, intersecting the perpendiculars at *h'*, *l'*, *m'*, etc.

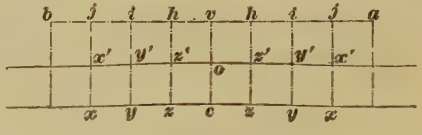


FIG. 20

Now, on a line *a b*, Fig. 20, the points *v*, *h*, *i*, *j* are set off on each side of the perpendicular centre line *c v* at a distance from each other equal to *v h*, *h i*, *i j*, etc., Fig. 17. From these points the lines *j x*, *i y*, *h z*, etc., are drawn perpendicular to *a b*, and the distances *j x'*, *j x*, *i y'*, *i y*, *h z'*, *h z*, etc., are set off on these perpendiculars equal, respectively, to the distances *m' x'*, *m' x*, *l' y'*, *l' y*, *h' z'*, *h' z*, etc., Fig. 17. Through the points *o*, *z'*, *y'*, *x'*, etc., and *c*, *z*, *y*, *x*, etc., curved lines are drawn, giving the proper shape for the front and back edges, respectively, of a plank that is to be bent over a prepared centre to form the semicircular arch bar of the sash.

49. The radial bars in the sash head shown in Fig. 17 have different curves, according to their positions. No. *1* is straight, as it is in the centre of the convex surface, and is parallel with the axis of the cylinder, of which the curved front of this window forms a part. No. *3* is curved to the arc of a circle, the radius of which is the same as that of the window plan, because it is

parallel to the base of the cylinder of which the curved front forms a part. No. 2, however, being parallel with neither the axis nor the base, takes a diagonal direction round the surface of the cylinder, and is therefore curved to the form of a portion of an ellipse.

To set out the face mould from which this elliptical curve may be marked on the plank for the radial bar, proceed as follows: Divide the length of the radial bar in Fig. 17 into any number of equal parts by the points i', n', p', q', etc., and drop from each division a perpendicular line intersecting the lines on the curved plan at $r'\ r''$, $s'\ s''$, etc. Then, on a horizontal line, as $v'\ u'$, Fig. 21, set off the distances $v'\ n$, $n\ p$, $p\ q$, etc., equal to $i'\ n'$, $n'\ p'$, $p'\ q'$, etc., Fig. 17, and set off on the perpendiculars erected at these points the distances $v'\ h$, $n\ r$, $p\ s$, etc., equal to $x''\ x'''$, $r''\ r'$, $s''\ s'$, Fig. 17; then, through the points h, r, s, t, u, draw a curve, which will give the outside line of the face mould required. The inside line of the face mould is then found by drawing a curve through the points h', r', s', etc., which are set out so as to make the distances $h\ h'$, $r\ r'$, $s\ s'$, etc., equal to the thickness of the sash on the lines $x'''\ x''$, $r'\ r''$, $s'\ s''$, $t'\ t''$, etc., as shown on plan in Fig. 17.

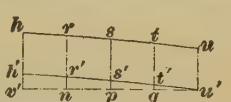


FIG. 21

DESIGN OF WINDOWS

50. Design.—To obtain a pleasing appearance and proportion, a good rule is to make the height of the window twice its width. To obtain a uniform frieze line round rooms in dwellings, it is well to keep the window and door heads equidistant from the ceiling. Thus, where the walls are 10 or $10\frac{1}{2}$ feet high and the doors 8 feet high, the top of the casing is from 18 to 24 inches from the ceiling. This space may be occupied by frieze and cornice, or a picture moulding may extend round the room in line with the upper edge of the door and window casings. Where ceilings are not over 14 feet high, this same effect can be obtained by introducing transom sashes over the doors, and filling these with either plate glass or art glass. In living rooms transom sashes often look out of place, so the space above the doors is left plain.

The glass line of windows in dwellings should be about 30 inches from the floor for principal rooms and about 36 inches for bedrooms. In all cases, the heads of windows should be as near the ceiling as the construction and interior scheme of treatment will permit, to obtain better light and ventilation. The meeting rails of the window sash should be placed not less than 5 feet 9 inches above the floor; otherwise, the rail will be on a level with the eyes, obstructing the view and detracting from the effect of the window. On this account, the height of the upper sash is sometimes made only one-half that of the lower, or one-third the clear height.

SKYLIGHTS

51. Construction.—It is often necessary for apartments and passages in a building to obtain light and ventilation from openings in the roof, known as **rooflights,** or **skylights.** These are of many forms, and may be made in wood, metal, or both The construction of a skylight on a sloping roof is shown in Fig. 22. In (*a*) is shown the plan; in (*b*), a section through it. The rafters *a*, *a* are stopped by the trimmers *b*, *b*, which run at right angles to the joists and hold their ends where they are cut to form the opening in the roof over which the skylight is to be placed. At *c*, *c* are the side rails of the skylight sash, *d* is the bottom rail, *e* the top rail, and *f*, *f* the glazing bars, or astragals. The sash rests on a curb *g*, *g* which is framed entirely round the opening on top of the trimmer *b*, *b*. The sash is usually framed the same as a window sash, but it is often made of heavier material.

52. The details of construction are shown in Fig. 22 (*c*), which is the section, to a larger scale, through the skylight. The main rafters *a*, *a* are stopped, or *trimmed*, on the trimmer *b*, which forms the opening in the roof. On this trimmer is fixed the curb *g*, *g*, which is rabbeted on its top side, as shown at *c*, *c*, so that the skylight may rest upon it and form a water-tight joint. The bottom rail *d* and top rail *e* are rabbeted on their under side to fit the rabbet in the curb *g*. The top rail *e* is thicker than the bottom rail *d*, because the glass of the skylight is let into a rabbet *h* of the top rail and fixed with putty, as

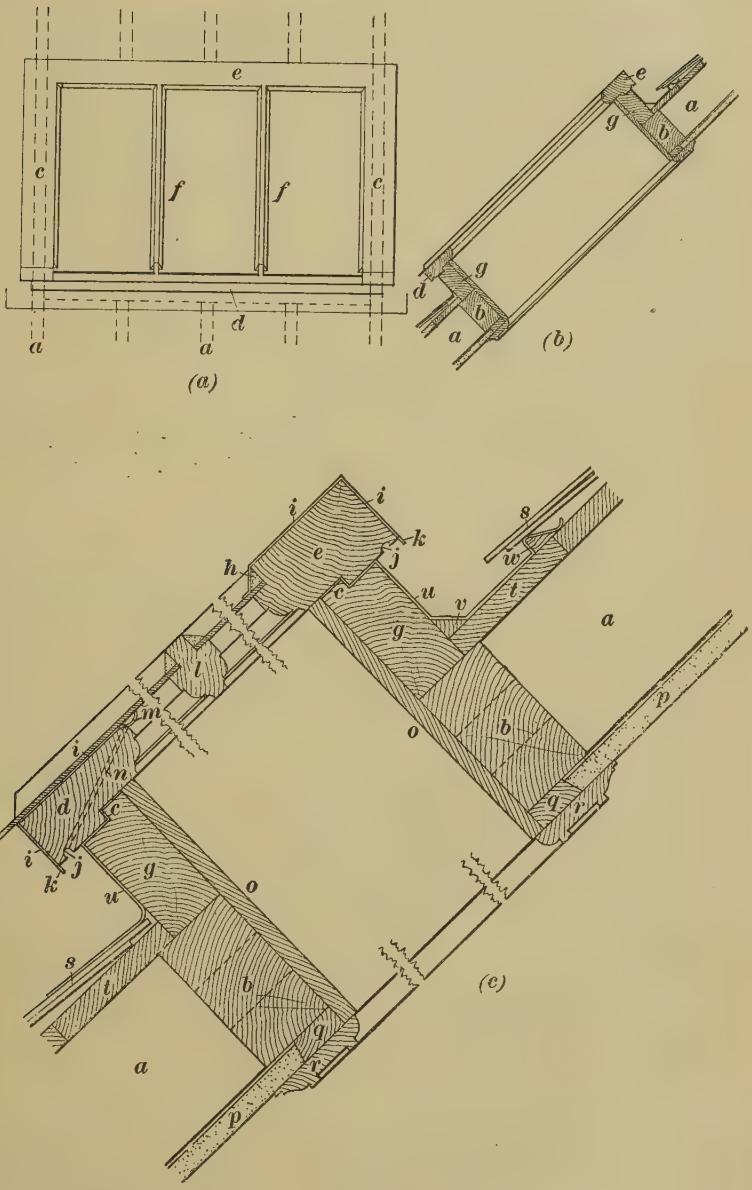

e
c
f
f
c
d
a
a
(a)
e
a
g
b
g
d
b
a
(b)
i
i
k
e
j
h
c
u
v
s
w
t
a
g
l
m
i
n
d
c
i
j
k
g
o
u
o
b
p
q
r
s
t
b
q
r
a
p
(c)

Fig. 22

to an ordinary sash. But the glass runs over the lower rail *d*, so that water running down its face may be carried off to drip on the roof below.

The sheet-lead covering *i*, *i* is often dressed over the wooden sash to protect it from the weather. In the case of the top and side rails, it is often dressed over the putty up to the glass, so that any water running from the lead may be brought right on to the glass to run away rather than on to the putty joint. A groove *j* is worked on the under side of the sash, so that any water finding its way past the lead drip *k* may not run into the inside of the skylight, but may drip off again on to the roof. At *l* is shown a section through the glazing bar, the construction of which is similar to that for windows.

53. Condensation.—Since, as a general rule, the interior of a building is considerably warmer than the exterior, especially during cold weather, a dampness or condensation forms on the under side of the glass. To prevent this dripping into the apartment below, a channel *m* is formed in the lead covering the lower rail. The moisture will then run down the under side of the glass into this channel, and find its way to the outside by the groove *n* shown by dotted lines. These grooves are made in the lower rail, at intervals of about 2 feet 6 inches, or 3 feet, along the width of the sash, and are connected with openings in the channel *m*.

54. Finishings to Skylights.—The finishings to the inside of a skylight may be made in several ways, but one method is shown in Fig. 22 (*c*). A finishing lining *o* is fixed all round the opening to cover the rough trimmer and curb. The lathing and plastering on the under side of the rafters is shown at *p*, while at *q* is shown the rough ground fixed next the finishing lining of the skylight. At *r* is shown the moulded cover, which is mitred round the opening to form a finish and cover the joint between the plaster and the rough ground and lining. At *s* is shown the slates on top of the boarding *t*, which is nailed to the top of the rafters. The lead *u* forming a protection to the curb of the skylight is shown dressed over the slates to keep out the water. At *v* is shown a small wooden fillet, which is nailed on top of the boarding

against the curb, so that the lead may be carefully dressed over it in the form of a gutter; this will enable the water running over the edge of the slates *s* to find its way down by the sides of the skylight and thence down the slope of the roof. In good work the lead should be dressed over the rabbet on top of the curb, as shown at *c*, *c*. The tilting fillet *w* is used under the slates in this position in the same way that it would be used at the eaves of a roof.

55. Opening Skylights.—Skylights may be made as fixed sashes or may be made to open for ventilating purposes. The construction in either case is similar to that just described, but it should be carefully noted that when made to open, the hinges should be very strong and made of gunmetal or other non-rusting metal.

SHUTTERS

56. In order to prevent the strong sunlight from streaming through the windows of a building, these openings are often provided with **shutters**, which may be of several forms or combinations of two or more forms. There are two general classes; namely, *inside shutters* and *outside shutters*. The former may be *folding* or *rolling shutters*, or *Venetian shutters*, while outside shutters are nearly always of the same general pattern. The method of construction in each case is influenced largely by atmospheric conditions, but the general principle is the same in all cases. Inside shutters are usually made of wood to match the finishing of the room containing them, while outside shutters are nearly always framed of pine and painted to protect them from the weather. Outside shutters must also be constructed with consideration of the fact that they are likely to be subjected to rather rough usage through the influence of high winds and rapid changes of temperature.

57. Inside folding shutters make a very neat, as well as a most useful, fitting for the inside of a window, and they should be so arranged that, when closed into their box, the exposed leaf will show a panelled finish on the inside of the room, as shown at *d*,

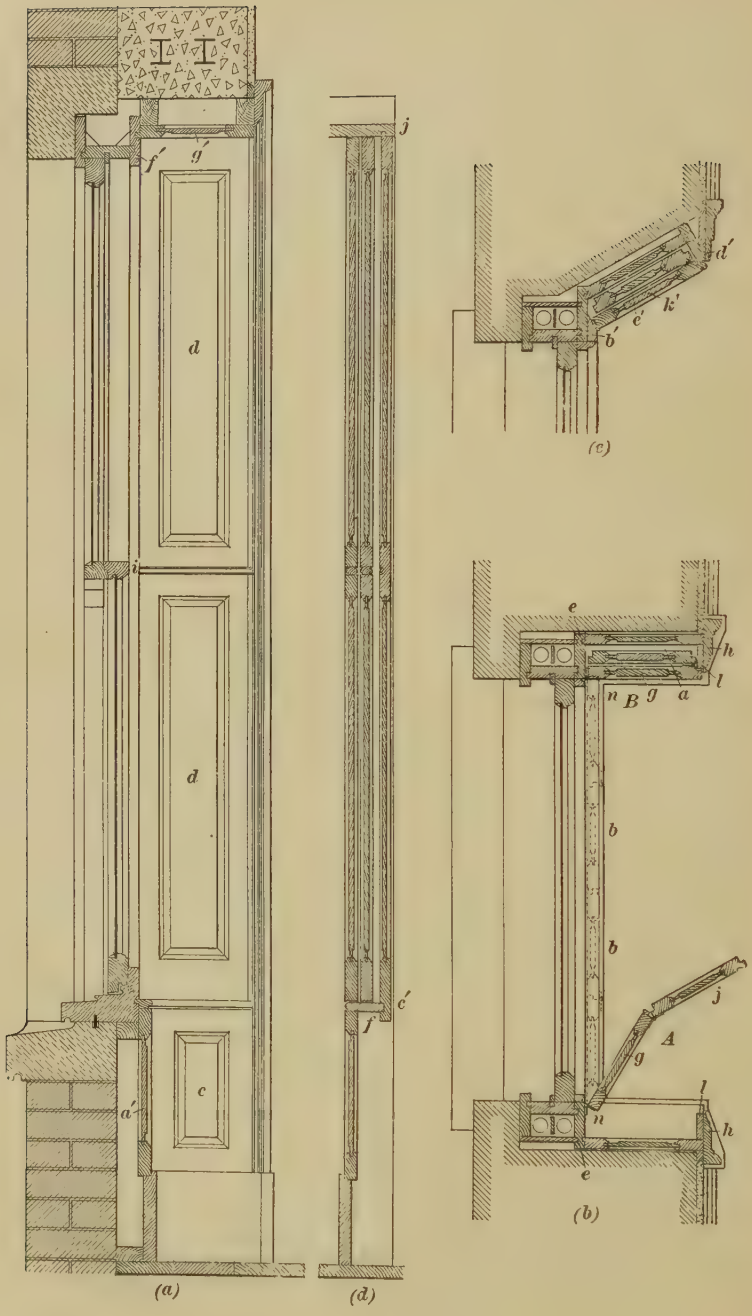


Fig. 23

Fig. 23 (*a*). These leaves are usually folded into a square jamb, as shown in the plan, Fig. 23 (*b*), although, when circumstances will permit, they are folded into a splayed opening, such as is shown in (*c*), in which case the panel work shows up to better advantage and the room is rendered lighter.

58. In Fig. 23 (*b*), the full plan of the window is shown with the leaves closed into the box at *a*, while the dotted lines at *b* indicate the position of the leaves when opened out of the box and closed over the window sash. The extreme width of the leaves between the outside hanging stiles *n* is $1\frac{1}{2}$ inches more than the width of the window between the pulley stiles, and is divided into four parts, each one of which represents the width of a leaf, or wing. These sections are framed together in one piece, from the inside sill to the window head, in the same manner as the rails and stiles of a door. The space between the window sill and the floor is often covered with a *panelled back*, or *breast*, as shown in section at *a'*, Fig. 23 (*a*); its return under the shutter box is shown at *c*. This panelled back is generally panelled similarly to the shutters and is constructed in the same manner as the panelled shutters.

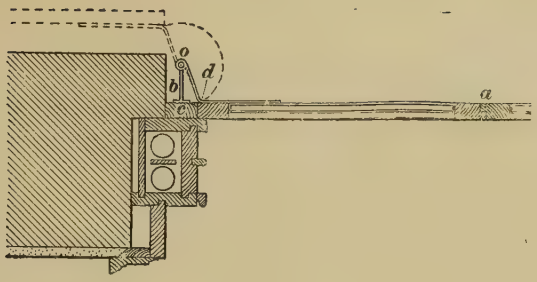
59. In Fig. 23 (*d*) is shown a section through the panelled back and shutter box. At *f* is shown the bottom of the box, housed into the lining *c'*, which forms the back of the inside of the shutter box and is secured at the top by a tongued-and-grooved joint into the soffit piece *j*. This soffit piece is panelled to match the shutters and panel back in the jambs, as shown at *g'*, Fig. 23 (*a*), and is secured by a tongue worked on its edge and let into the window casing at *f'*. The inside lining *e* of the weight box, Fig. 23 (*b*), in the window frame forms the outer lining of the shutter box, and the inner lining of the latter, as shown at *l*, is attached to and forms a part of the interior finish or architrave *h*. The panelled shutters *g* are hinged to the hanging stile, as shown at *n*, while the leaf *j* is hinged to *g*, so that the knuckle of the hinge is entirely within the edge of the stile of *g*. This method of hanging permits the shutter *j* to swing back sufficiently from the edge of the stile to secure it from any danger of catching on or against the edge of the

architrave, or the shutter stop, when the leaves are closed into the box, as shown at *B*. At *A* the leaves are shown half open. This is still further accomplished by making the leaf *j* $\frac{3}{4}$ inch narrower than the leaf *g*, so that there will be no tendency for it to become jammed in the box. The rabbeted joint between the two leaves *g* and *j* is only $\frac{3}{8}$ inch deep, and is provided simply to secure a light, tight joint.

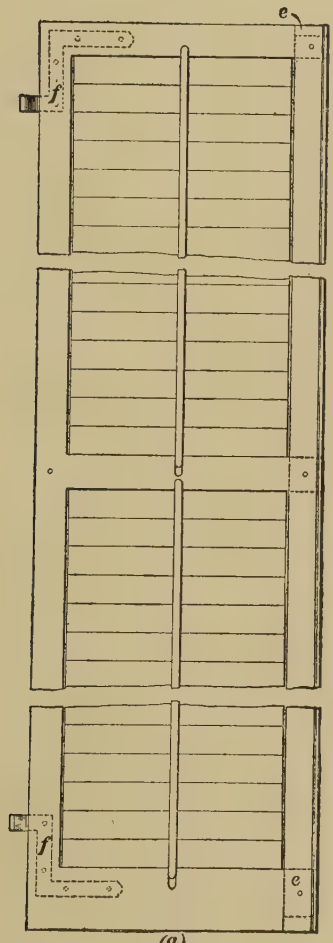
60. When the jambs of the window are splayed, as shown in Fig. 23 (*c*), there is only a slight difference in the construction of the shutters themselves, although the box requires a little extra attention. At the outside edge of the box, on the side next to the window, the extra hanging stile *b'* is introduced, to provide a proper depth at the front edge of the box for the panelled shutter *k'* to shut into. Without this, the leaf would close back no farther than in the square jamb shown in Fig. 23 (*b*), unless the edge was bevelled to suit the splay. The box jamb *d'* is also necessary at the inner side of the box, to form a satisfactory stop for the shutter and to make a neat finish to the box itself. In splayed window jambs, the shutter *e'*, which folds inside, must be made from $1\frac{1}{2}$ to 2 inches narrower than the exterior shutter *k'*.

61. When inside shutters are required for a window, it is first necessary to set out a measuring rod, with the stiles, rails, and panels marked as described for the framing of doors, etc. The entire shutter, from the sill to the window head, is set out and constructed in one piece, and then sawn apart at the centre of the meeting rails, as shown at *i*, Fig. 23 (*a*). The leaves are temporarily hinged and hung in place, so as to ensure their proper fit, and the marks are then made at the meeting rails, to which the shutters are afterwards sawn, thus forming an independent set to cover the upper and lower sashes.

62. **Outside shutters** differ from inside shutters only in such details of construction as their more exposed situation requires. In Fig. 24 (*a*) is shown the inside elevation of one type of outside shutter, while in (*b*) is shown its plan. The hanging stile for the shutter on the window frame is shown at *c*, and the form of hinge necessary to permit the shutter to open round the angle



(b)



(a)

FIG, 24

of the brickwork is shown at *b*. The shape of this hinge and its attachment to the shutter are shown by the dotted lines at *f* in Fig. 24 (*a*). The angle in the hinges permits them to extend over the joints at the top and bottom rails, and thus add strength to the shutter, besides rendering it more secure in high windstorms than would the ordinary hinge. The extreme length of the arm *o b* carrying the pin half of the hinge permits the shutter to swing round the outside of the brick wall clear of the opening, as shown by the dotted lines, but the corresponding length *o d* causes the shutter, when opened, to move first in the direction *d a*, and is likely to cause the shutters to bind when they are opened. This tendency, however, is taken care of by the thinness of the metal of which the hinges are made, as they can be easily bent out of place a sufficient distance to permit the shutters to open at the centre and swing clear.

63. Outside shutters are set out with a measuring rod in the same manner as doors and other framed work, the lengths of stiles and rails, the positions and lengths for tenons, etc., being all marked on the measuring rod before any of the actual framework is even started. The positions and proportions of the mortises and tenons in this shutter are shown by the dotted lines at *e*, Fig. 24 (*a*), as are also the tightly driven pins that hold the joints in place. As glue would be useless to secure the joints of outside shutters, owing to their exposed situation, the fixed parts are often fitted together with white lead. The movable joints of the louvres, however, require nothing to make them secure except a proper consideration for the accuracy of construction and the effects of probable expansion and contraction.

64. Fig. 25 shows a section of the top rail of the shutter and four of the louvres. The thickness *a b* of the stile varies, but is never less than $1\frac{1}{8}$ inches. The holes shown dotted at *d* have a diameter equal to the thickness of the louvres, which thickness varies with the size and weight of the shutter. The holes are bored from $\frac{3}{4}$ to $\frac{5}{8}$ inch from the outside of the stile, and should be exactly $\frac{1}{4}$ inch deep. The pins on the ends of the louvres are exactly $\frac{11}{32}$ inch in length, thus leaving at each end

of the louvres $\frac{3}{32}$ inch to allow for painting and to permit freedom of movement. The louvres are operated by a rod that is attached to each louvre by means of two **U**-shaped staples, one of which is forced into the middle of the edge of the louvre, while the other is driven into the rod itself, as shown at *e*. Thus, when the rod *f* is pulled down, each louvre is thrown to the horizontal position shown by the dotted lines *j*, thereby admitting light and air through the shutter. The top stile *c* is cut out, as shown at *h*, to receive the upper end of the rod *f* and the upper staple when the louvres are closed in the position indicated in the illustration.

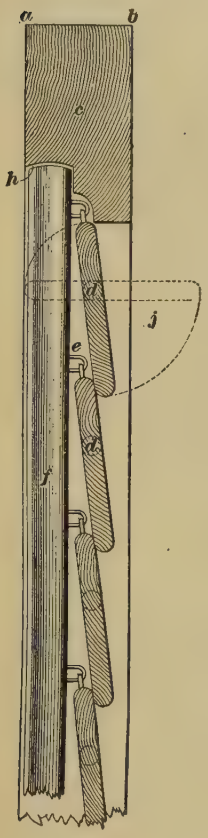


FIG. 25

Shutters of this character are made with two, three, or four panels of louvres, according to the height of the window on the stile of which they are hung, each panel being separated by a horizontal rail from the one next above or below, and each set of louvres being operated by a separate rod, as shown in Fig. 24. In the case of an unusually high shutter, however, the two upper sets are sometimes operated by one long rod, which extends over both panels and moves in a groove, cut across the separating rail, when the louvres are closed.

65. Hinging Inside Shutters. — Fig. 26 shows an inside window-frame casing at *e*, to which the shutter *b* is hung. The shutter as it stands in the box is shown at *b*, while at *a* it is shown dotted in position as closed across the window. At *c* is shown the second leaf in line with *b* when open, and at *d* its position when folded in the box. In hinging the leaf *b* to the casing *e*, the whole thickness of the hinge *e'* is let into the edge of the shutter, and the flap of the hinge is screwed to the face of the casing *e*. The knuckle of the hinge should project just beyond the face

of the shutter *b*, as at *z*. When the hinge is placed as shown, making *a′ b′* $\frac{1}{2}$ inch from the edge of casing to face of shutter, then, when *b* swings on its hinges to the position *a*, the edge of the shutter will be at *c′*, which is $\frac{3}{16}$ inch from *b′*, or $\frac{11}{16}$ inch from *a′* ; therefore, in making the shutters, the width must be

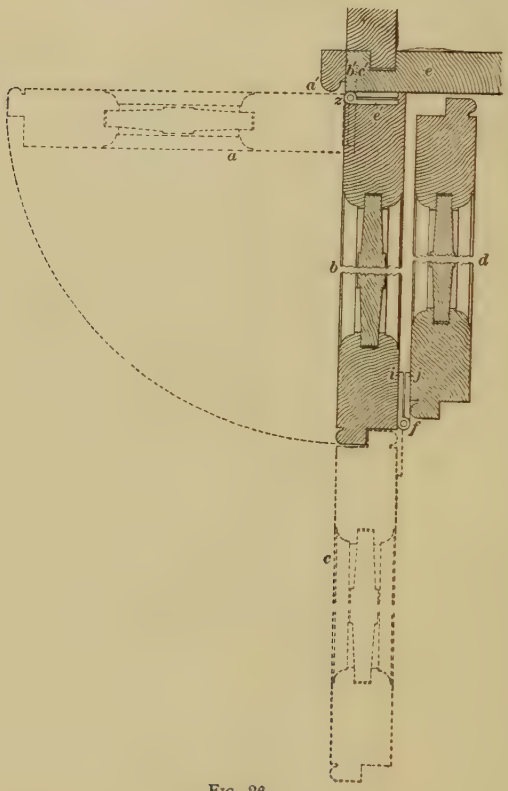


Fig. 26

taken from *c′* in order to show the $\frac{1}{2}$-inch margin of the casing when the shutters are open. The flap hinge *i f j* is screwed to the inside face of the shutters, thus keeping the knuckle of the hinge all on the elbow blind *b*. This is done to prevent the edge of the flap blind *d* from striking when folding the two shutters in the box.

66. Hinging Outside Blinds.—Fig. 27 (*a*) shows a plan of the shutters to a window in a brick or stone wall. At *b* is shown the position of the shutters when closed, and at *c* is shown the shutter when opened. At *a* is shown the lining fixed to the outside lining of the sash box to which one-half of the hinge is

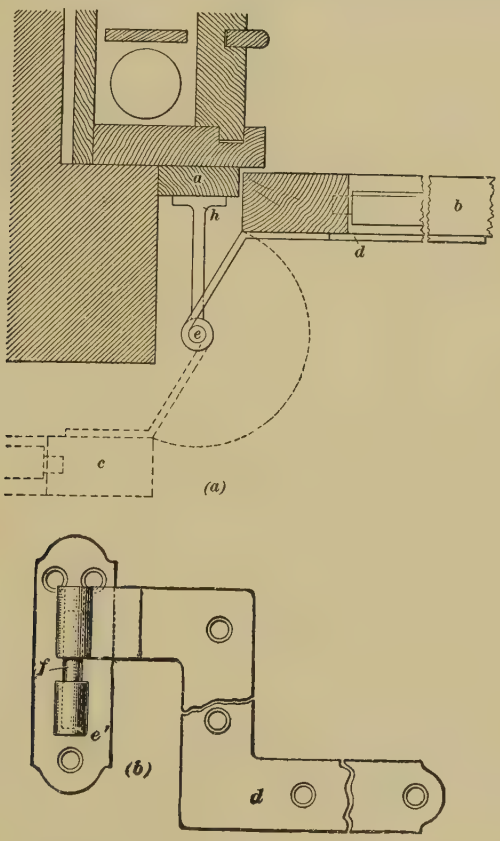


FIG. 27

screwed, as at *h*. The hinge is in two parts, as shown in (*b*), and consists simply of an iron strap *d* with a socket to fit round the pivot *f* that is secured to the other half of the hinge. The iron strap *d* is screwed to the shutter *b* and is secured by means of the pivot *f* in the socket *e'*.

INTERIOR FINISHINGS

67. It is the work of the joiner to apply the door and window casings, skirtings, wainscoting, chair rails, panelled jambs, etc., and to hang the doors, sashes, transoms, etc., that fit into the openings he has trimmed or cased. Grounds should be placed by the carpenter round the margins of all openings, along the lower edge of the side walls, and wherever necessary to attach any portion of the interior finishings, as thereby a straight and rigid base is secured for the attachment of the woodwork, and the breakage of the plaster adjacent to the woodwork while the finishing is being nailed in place is prevented. In all the examples of finishings to doors and windows in this Section, the plaster has been shown attached directly to the wall face. In Scotland and other parts, especially in very exposed situations, brick and stone walls are first *furred*, or *strapped;* in other words, battens are fixed upon their faces on the inside to which laths are nailed, as to a partition, to receive the plastering. By this means the inner plaster face is kept dry.

68. Architraves.—The term **architrave** is given to a casing that is used round door and window openings. It is so placed as to conceal the joint between the wooden ground and plaster. Thus in Fig. 2 (*c*), *p* is the architrave covering ground *o* and plaster *q*. Architraves are sometimes richly moulded or elaborately carved, but, except in specially designed work, it is better to keep them as simple and plain as possible. Where architraves extend to the floor, they must be thick enough to receive the end of the skirting, but they may stand on *plinth blocks r*, Fig. 15, that project beyond their face and form both a base to the architrave and a stop for the skirting. The architrave is attached to the ground *o*, Fig. 2, after the plastering is thoroughly dry, and is so placed that its outside edge will extend well over and cover the joint between the plastering and the ground.

69. The upper corners of the architrave may be joined in several ways. In Fig. 28 (*a*) is shown the proper way to joint an architrave of that particular form. The fillet mould should be mitred, the flat or fascia section butt-jointed, and the back band

mitred. For a mitred architrave, a hardwood tongue, or spline, should be inserted as shown in (*b*), the grain of the tongue running at right angles to the mitre cut. The groove for the tongue is cut in the shop or mill with a circular saw. A joint made in this way, if the wood is reasonably dry, will hold together well. Long mitred joints, sometimes used in architraves round doors and windows, should be avoided as much as possible, as it is difficult

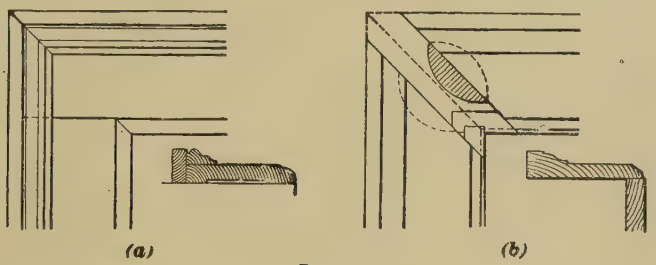


Fig. 28

to prevent the opening of the joint due to shrinkage of the material. Sometimes, in cheaper work, corner blocks are used to stop the architrave against, instead of mitreing it at the angles. These, however, are not to be recommended, not only on account of their inartistic appearance, but also on account of their tendency to shrink and leave unsightly cracks on both sides of the doorway. The architraves should be securely nailed both to the ground and to the jamb or lining all round the opening.

70. Facings.—**Facings** are similar to architraves, only smaller and thinner, and are usually moulded on both edges. The outer edge is usually run with a moulding similar to that of the skirting, to which it is mitred, thus dispensing with a base block. Facings are usually fitted in kitchens and bedrooms.

71. Skirtings.—The **bases**, or **skirtings**, of a room consist of a band composed of one or more boards from 6 to 18 inches wide, running round the bottom of the walls, to protect the plaster. The skirting board may be plain, or it may have a moulding worked on it, as shown in Fig. 29 (*a*), or it may

consist of a plain board with mouldings applied independently to give it a finish, as shown in (*b*). When the skirting is very wide and is made up of more than one width of boards, it is sometimes desirable to have the lower member *a*, Fig. 29 (*b*) and (*c*), project beyond the upper one, thus forming a sort of plinth round the room. The joint between the skirting and the floor should be as close as possible.

In (*c*) is shown a skirting that is only used in first-class work, as it is expensive to execute. This form is not recommended,

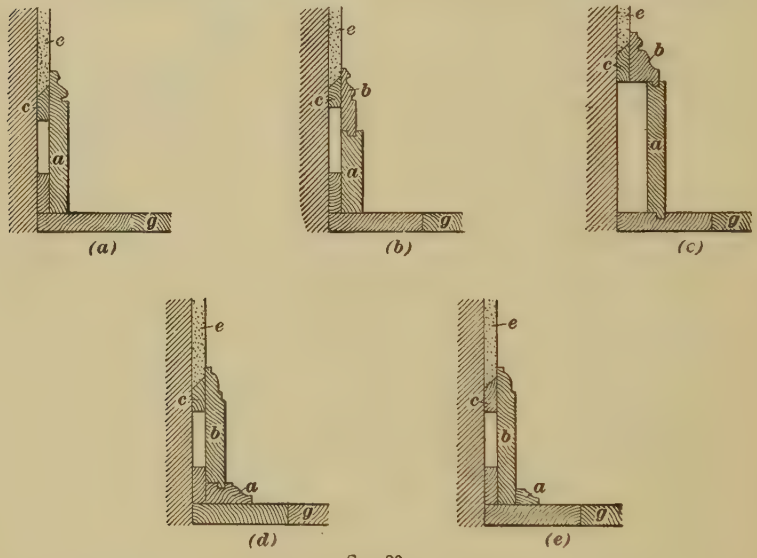


Fig. 29

however, as the space between the baseboard and the wall provides a good run for mice and other vermin. The baseboard *a* is grooved and tongued into the floor boards *g* and has, in turn, a moulded cap *b* housed in it. This cap is securely fixed to the rough ground *c*. In (*d*) is shown another type of skirting. Here a moulding *a* is fixed on top of the floor boards *g*. Grooved and tongued into it, and securely fixed to the rough ground *c*, is the moulded face piece *b*. In (*e*) is shown a skirting similar to (*d*), except that the face piece *b* goes down to the floor level and the moulding *a* is simply fixed in front of it. The

spaces between the wall and face board of a skirting are often filled in with plaster, to keep out vermin.

72. Dados and Wainscots.—In rooms where the position of the furniture is frequently changed, such as dining rooms, libraries, and kitchens, as well as in bathrooms, halls, and staircases, it is sometimes desirable to affix a *chair rail* to a narrow ground. This is a broad band, or moulding, about 3 feet from the floor and parallel with the skirting, which prevents the backs of chairs from injuring the wall. It forms a cap to the dado, or wainscot, if such is desired, and covers the joint between the ground and the plaster. The space between the chair rail and the skirting is called the **dado,** or **wainscot**; it may be panelled in wood, covered with narrow lining, or simply left plain in plaster.

73. In a panelled wainscot, such as is shown in Fig. 30, great care is necessary in fitting all the joints. Due consideration

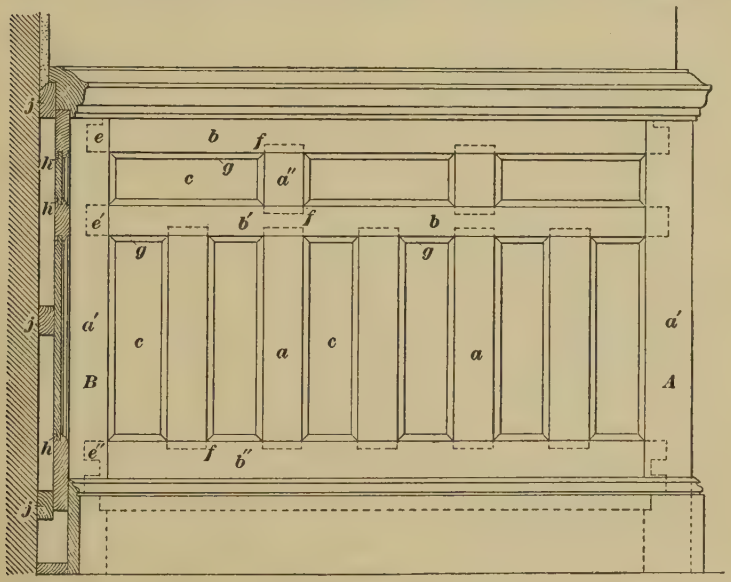


Fig. 30

must be given to shrinkage, so that the drying out of the material will not cause unsightly cracks or open joints. The vertical pieces *a*, *a′*, and the horizontal members *b*, *b′*, and *b″*, that divide

the surface into panels *c* are framed and glued together. The end stiles *a'* extend from the floor to the upper edge of the top rail *b*, and are mortised to receive the tenons of the rails *b*, *b'*, *b''*, as shown at *e*, *e'*, and *e''*. The rails are also mortised, and receive the tenons of the intermediate stiles, or muntins, *a*, *a''*, as shown at *f*. The edges of the panels *c* are either bevelled off or hollowed out and inserted into a groove worked to the depth of the moulding *g* in the edge of each stile and rail, as shown at *h*. When small, the mouldings *g* may be worked on the edges of the stiles and rails, but, when large and heavy, they must be worked from separate stock and fitted in position afterwards. The panels are thus practically separate from the surrounding frame, and are free to shrink or swell without danger of splitting. At the same time, since the amount of cross-grain in the extent of the wainscot is equal only to the sum of the widths of all the stiles in one direction and to the widths of all the rails in the other direction, the shrinkable material is reduced to a minimum, so that the wainscot, when constructed with well-seasoned material, will give good results.

74. Where the face of the wainscot is to be a plain unpanelled surface of wood, still further precautions must be taken to guard against the effects of shrinkage and warping. Two general methods are recognized as satisfactory for this purpose. One is to make the wainscot of narrow boards, not more than three times their thickness in width, with the grain in each piece reversed with reference to that of the adjacent one ; that is, to have the heart side of the material show on each side at every second board. After being tongued and grooved and glued together, the boards are secured against warping by keys inserted as described in *Joinery*, Part 1.

75. The other method is to build the wainscot with several thicknesses of thin stock, reversing the grain in each piece. This is the better method for long, unbroken surfaces, as shrinkage is prevented almost entirely ; but when the design of the wainscot will permit the building of a stile, or pilaster, every 6 or 8 feet, the narrow, keyed boards will be found to serve very satisfactorily provided $\frac{1}{2}$-inch space between the ends under

the pilasters is left to allow for expansion and contraction. These keyed sections, if the grain runs vertically, should be secured to the wall only in the centre of their lengths, and left loose the rest of the way to come and go with atmospheric changes. If the grain runs lengthwise of the wainscot, no stiles, or pilasters, will be required to cover the joints, as the wainscot can be built up of one continuous piece, but the shrinkage between the base and the coping, or surbase, must be provided for, and the wainscot should be secured only in the centre of its height, so as to allow the top and bottom to come and go.

76. After the panelling of the wainscot is completed, it is secured to the grounds *j*, Fig. 30, which are set in place to receive it, before the plastering is applied. Every possible precaution must be taken to ensure the drying of the plaster, as the presence of the slightest moisture is disastrous to permanent joinery work. Under the most favourable conditions, at least a week should be allowed to dry each of the first two coats of plaster, and, if possible, the finishings should not be applied for 4 weeks after the finished coat is spread. In damp or rainy weather much more time should be allowed. The patent prepared plasters and wall cements dry in less time than this, and a deduction can be made when these are used, according to the rapidity of their drying.

77. When the wainscot is secured horizontally through its centre, and allowed to shrink at the top and bottom, a horizontal ground must be provided to nail it to, and additional grounds must be provided at top and bottom to secure the capping and the base, as well as to form a backing for the upper and lower edges of the dado. When the wainscot is secured along vertical lines every 8 or 10 feet of its length, vertical grounds must be provided in addition to the grounds at top and bottom.

78. **Setting Out.**—In setting out and spacing the stiles, rails, and panels of a wainscot, it is first necessary to prepare a long measuring rod, about 2 inches wide. After a line *a b*, Fig. 31, is drawn through its centre, the rod is divided into a number of spaces, corresponding to the widths of the stiles and panels on one side of the line, and to the width of the rails and length of

the panels on the other side, that is, the smaller divisions in Fig. 31 that are above the line *a b*, as *c d*, *l m*, *l′ m′*, etc., show the position and widths of the stiles *a*, Fig. 30, while the larger

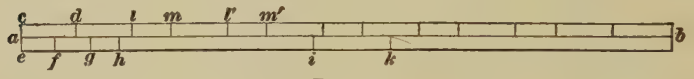


Fig. 31

divisions, *d l*, *m l′*, etc., show the width of the panels *c*. The divisions *e f*, *g h*, and *i k* below the line *a b*, Fig. 31, mark the widths of the rails *b*, *b′*, and *b″*, Fig. 30, and the spaces *f g* and *h i* show the width and the length of the panels.

79. The three rails *b*, *b′*, *b″*, Fig. 30, are clamped together with hand screws, after which the rod is used to set out the width of, and the spacing between, the stiles. These divisions are then squared across the three rails, and marked with a scratch awl or the point of a knife. The stiles are then marked in the same way, three or four at a time, and an allowance is made for the length of the tenons on the ends. In setting out the measuring rods for the spacing of the stiles and panels, it should be remembered that a stile must exist on each end of the wainscot. To determine the number of panels required, the width of one stile and twice the thickness of the wainscot must be subtracted from the length of the room, if the wainscot returns on two interior angles, and the remainder divided by the sum of the widths of one panel and one stile. If, however, the wainscot returns round one exterior and one interior angle, as at *A* and *B*, Fig. 30, only the width of one stile should be deducted.

80. In Fig. 30, the length of the wall along which the wainscot is built is 3 feet 11 inches, and the panels are each $4\frac{1}{2}$ inches wide; all the stiles are 3 inches wide, except the end one *A*, which is $3\frac{1}{2}$ inches wide. If $3\frac{1}{2}$ inches, the width of the end stile, is subtracted from 3 feet 11 inches, the length of the wall, 3 feet $7\frac{1}{2}$ inches of wainscot remains to be divided into six equal panels and six equal stiles. The combined width of a panel and stile, therefore, is $43\frac{1}{2} \div 6 = 7\frac{1}{4}$ inches. Since the stiles are to be 3 inches wide, then $7\frac{1}{4} - 3 = 4\frac{1}{4}$ inches is the width of each panel opening. If the wall at *A* had returned on an interior

angle, like the wall at B, the end stile at A would have been of the same width as the stile at B, and it would then have been necessary to deduct 3 inches, the width of one stile, plus $2\frac{1}{4}$ inches, twice the thickness of the wainscot, from 3 feet 11 inches, which would give about $6\frac{3}{32}$ inches as the width of each panel and stile combined, and, allowing 3 inches for the stiles, each panel opening would be $3\frac{3}{32}$ inches in width. The panels themselves, however, will be wider than that, as a proper allowance must be made all round for their insertion into the grooves h.

81. After all the mortises and tenons are cut and fitted, and each has been marked so that it can be returned to the same place to which it was fitted, the pieces of wainscot are taken apart and laid in a pile preparatory to gluing. Either the shoulders and cheeks of the mortises near the shoulders or the tenons near the shoulders receive the glue, and the stiles are forced into the rails as soon as possible after the glue is applied. The lower stiles are glued in the bottom rail first ; then their upper tenons are covered with glue in the same manner, and the middle rail b' is forced over them, after the panels have been placed in position. The upper stiles are then glued into the middle rail. Finally, the top rail b is glued in place, and the whole form is drawn together with bench clamps until the glue is thoroughly dry.

82. In all joinery work framed together with mortise and tenon, care must be taken to clean out the mortises thoroughly and to dust off the tenons before gluing. Each tenon must be tried in the mortise to which it belongs, and any unevenness should be removed so as to ensure a proper fit. All framed work should have its parts heated thoroughly before being clamped and glued together. If, when a piece of work is being clamped up, any rail or stile has a tendency to warp, that rail or stile must be clamped in place with a bench screw under a piece of thick plank, and must remain this way until the glue is dry. Care should always be taken that an extreme pressure of the clamps does not cause the work to deflect, or wind, as it is important in all panelled work that the whole face of the frame be kept in place until the glue is thoroughly set, or dry.

83. Mouldings.—The most common forms of mouldings are known by builders as *stock mouldings*. Their price varies with their size. When other than stock moulding is required, an additional price is charged for the labour of making a new knife and changing the cutters in the machine. These mouldings are termed *special*, and add a little to the cost of the building, especially if a great variety is used. Some of the most common

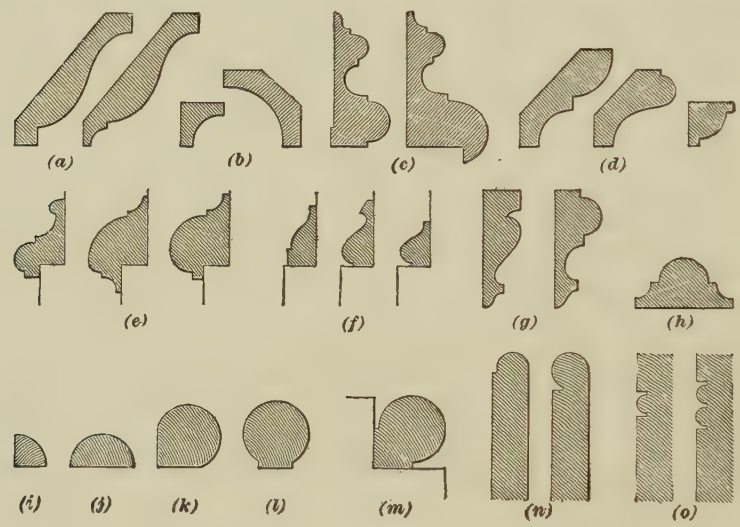


FIG. 32

forms of stock mouldings are shown in Fig. 32 ; they are named as follows : (*a*), ogee crown mouldings ; (*b*), coves ; (*c*), base mouldings for columns, etc. ; (*d*), bed, or stop, mouldings ; (*e*), raised panel mouldings ; (*f*), flush panel mouldings ; (*g*), band, or architrave, mouldings, sometimes used as base mouldings ; (*h*), astragal ; (*i*), quarter-round ; (*j*), half-round ; (*k*), three-quarter round ; (*l*), full round ; (*m*), three-quarter bead ; (*n*), bead ; (*o*), single- and double-centre beds.

INTERIOR FITTINGS

84. Washtubs. — Washtubs, though seldom made of wood now, are fixtures that the joiner may be called on to build, so a method of constructing them is shown in Fig. 33.

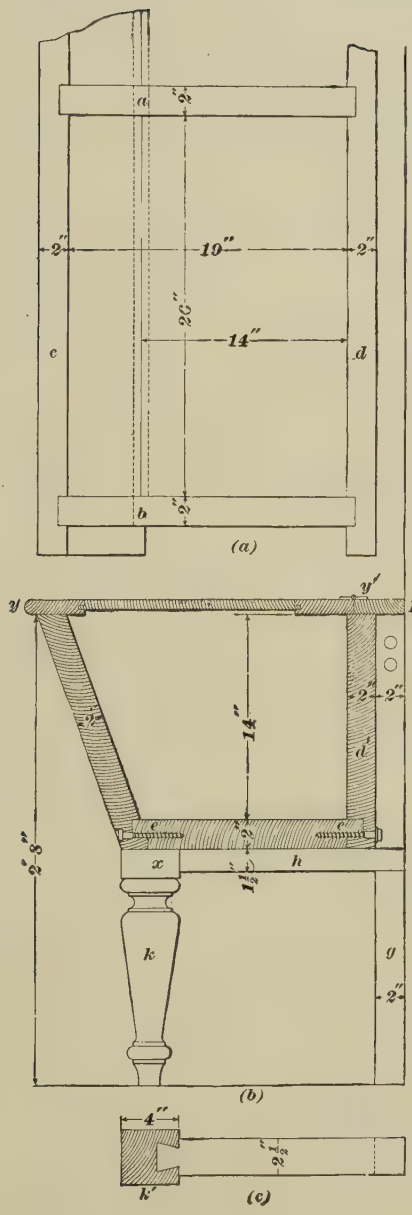


Fig. 33

In (*a*) is shown a plan, in (*b*) a vertical section, and in (*c*) the plan of the cross-piece under the tub and its joint with the turned leg, as shown at *x* in the vertical section. These tubs are built in either a kitchen or a laundry, and consist of from two to four divisions. In (*a*) is shown the end tub of a set. The partition *a* and end-piece *b* are shown housed into the front and back pieces *c* and *d*. All of these pieces *a*, *b*, *c*, and *d* are 2 inches thick, and are bedded at the joints with white lead. The bottom *c* is tongued and grooved into the sides, and is secured by means of lag-screws; this joint is also set in white lead. The panelled cover *y*, *y′* over the tubs is fastened with a brass hinge *y′*, while behind the tubs is shown a 2-inch space for pipes, etc. Extending over three-fourths of the thickness of the back piece *d′* is a wooden cap *f*, which finishes the top against the wall. A $2\frac{1}{2}'' \times 2''$ support *g* carries one end of the $2\frac{1}{2}'' \times 1\frac{1}{2}''$ beam *h*,

while the other end of the beam rests on, and is dovetailed into, the 4-inch leg *k*, as shown in the plan (*c*) at *k'*.

85. Butler's Pantry.—There is perhaps no part of a private residence where the joiner must do so much work in a small space as in the **butler's pantry.** The pantry must contain a long table for holding the crockery, etc., both before and after their service in the dining room, also a sink in which to wash dishes, glasses, etc. This must be well lighted from an adjacent window, while a dresser opposite or over the long serving table will receive them after they have been washed. Fig. 34 shows the plan of a butler's pantry suitable for a private house ; the details are applicable to either a town or suburban dwelling. The entrance *a* is provided with a sliding door, for economy of space. On the left at *b* is the long service table, 18 inches wide, where the dishes are placed or the carving is done before the food is served in the dining room. At one end of this table is the dumb waiter *c*, while at the other end, at *d*, is the drip board of the sink *g*. Opposite the serving table is the dresser *e* for the dishes, below which are closets *f* and drawers, shown in section in Fig. 36, for silverware, dishes, etc., as shown more in detail in Fig. 35.

86. There is no work in the construction of these pantry fittings that has not been described. The glazed doors of the dresser *e'*, Fig. 35, are constructed in the same manner as a hinged window sash. When the dresser is not over 7 feet long, it is sometimes advantageous to close the front with three glazed sashes. These sashes are ploughed with a groove in the top and bottom rails, and are arranged to slide the full length of the dresser on hardwood or metal tracks, which are secured just far enough apart to permit the sashes to clear one another in sliding, or they may be made in pairs and hinged as shown on the elevation. The shelves in the dresser may be fixed permanently in place and varnished on both sides, so as to prevent any dust from sticking to them or collecting round the dishes. The drawers *g'* are provided for silverware, such as forks, knives, spoons, etc., and the shelves in the closets underneath are for linen and the larger pieces of tableware that cannot conveniently be put in the upper part. The glazed closets *e'*

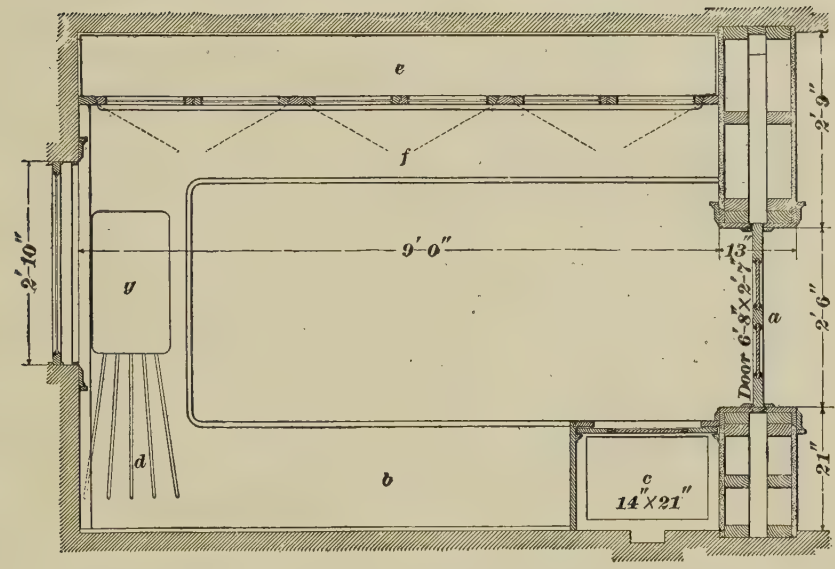

e
f
g
d
b
c
14"×21"
a
9'-0"
13"
Door 6'-8"×2'-7"
2'-10"
2'-9"
2'-6"
21"

FIG. 34

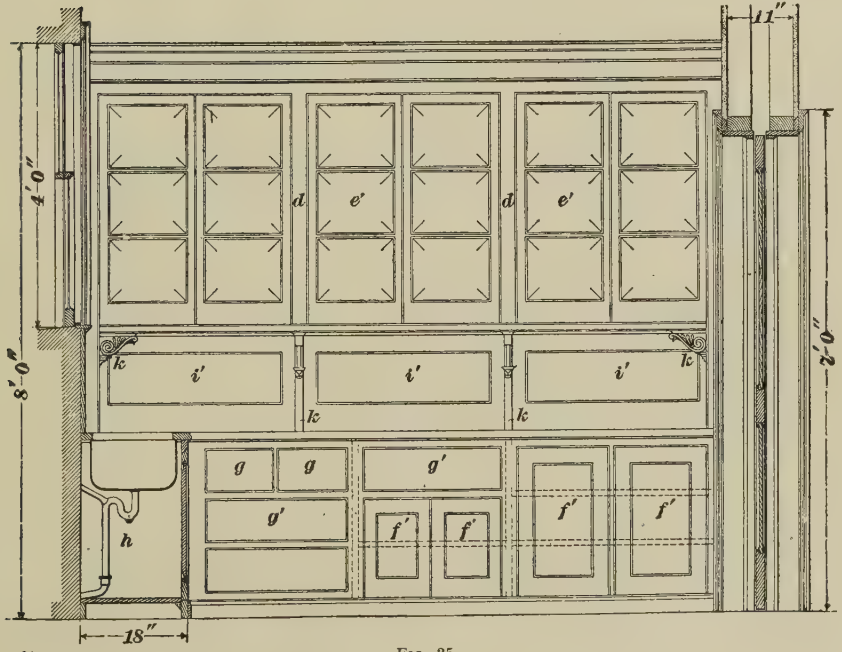

11"
4'-0"
8'-0"
2'-0"
18"
d
e'
d
e'
k
i'
i'
i'
k
k
k
g
g
g'
g'
f'
f'
f'
f'
h

FIG. 35

are placed about 18 inches above the top of the linen closets f', thus leaving a long narrow sideboard between, the wall side i' of which is panelled with plain, flat, unmoulded panels, similar to those in the doors below. The glazed closet is secured against the wall, but is supported by metal or wooden brackets k, placed one at each end of the closet and one under each mullion d.

87. In the section shown in Fig. 36, the window at the end of the pantry is shown at a'. Immediately under it is the sink g, Fig. 34. The board shelves over the serving table are shown in section at b, Fig. 36, and a section through the dresser shelves

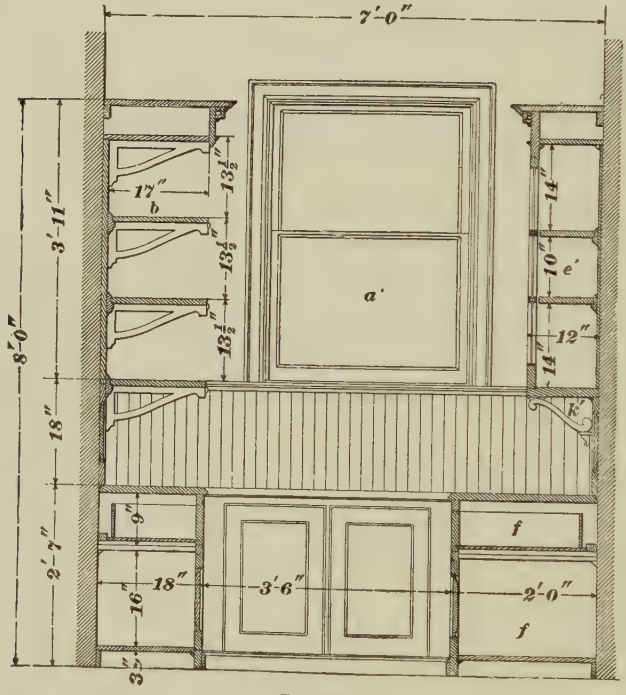


Fig. 36

is shown at e'. When the pantry is built in a suburban residence, it partakes more of the character of a storeroom, and requires at least one chest of smaller drawers, as shown at g, Fig. 35, for the storage of coffee, tea, sugar, spices, etc., while at one end

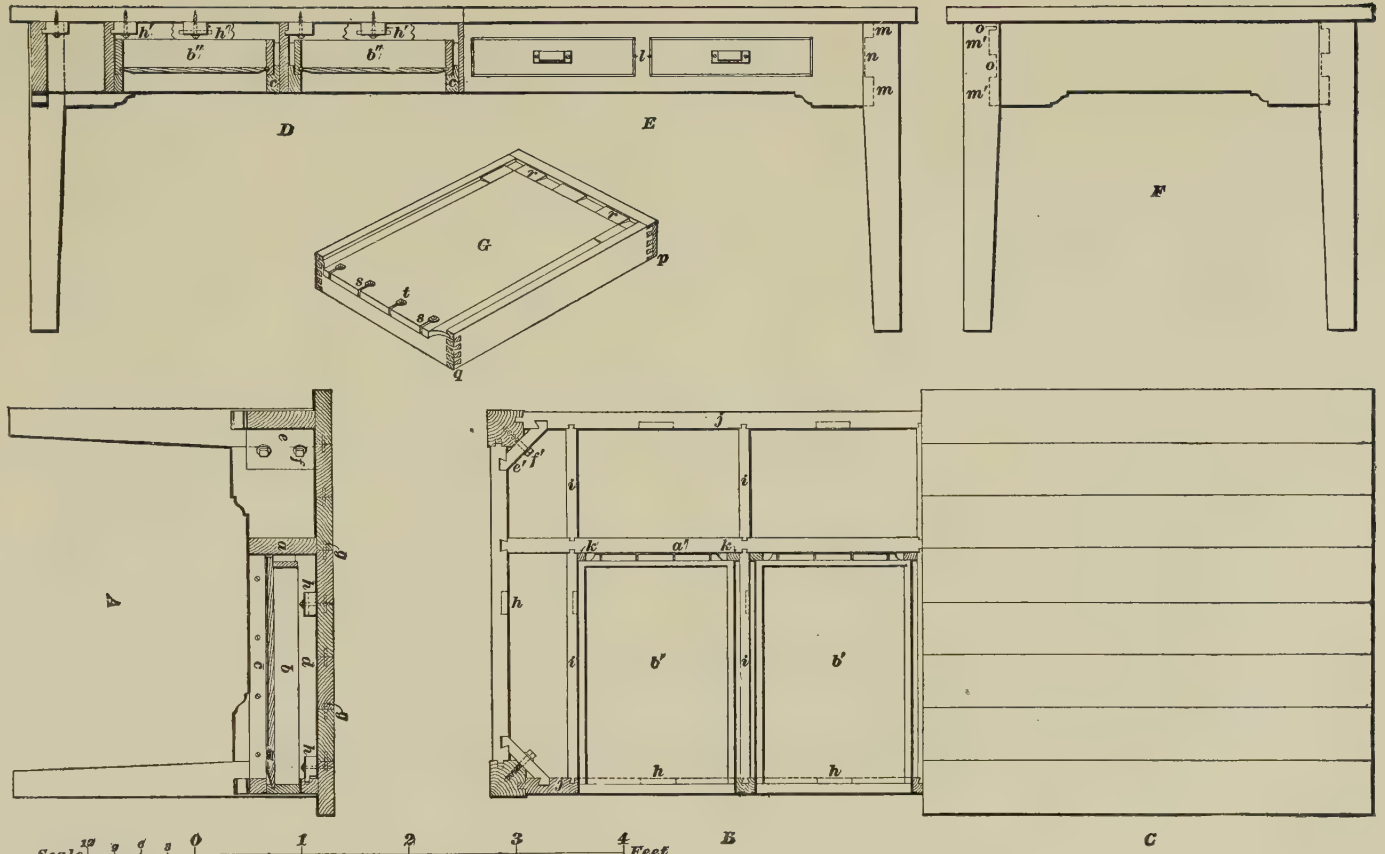


FIG. 37.

must be provided a proper compartment for a barrel or bag of flour.

88. **Serving Tables.**—Fig. 37 shows a kitchen serving table, 4 feet wide by 8 feet 8 inches long and 2 feet 8 inches high. Four drawers, 24 inches deep, may be placed along one side. The wide span between the legs, a heavy load on top of the table, the weakening of the front rail by the insertion of the range of drawers, and a top, 4 feet wide, which tends to warp from the heat of the kitchen, are points that require consideration. Plain, substantial, sound construction, with staying qualities, is required. To secure as much rigidity as possible to the front, or drawer rail, it is necessary to make the framework of some hardwood, so well-seasoned prime ash should be selected, for this material is well adapted for the purpose. To proportion the legs to the depth of rail required, they should be made 4 inches square at the head and reduced to 3 inches square at the foot. The rails should be $1\frac{7}{8}$ inches thick and 8 inches deep; this should be increased to $9\frac{1}{2}$ inches at the shoulders, so as to render the junction with the legs inflexible. The increase in depth should be treated as a corbel, or bracket. The end and back rails should be of solid material, while the framing of the front rail, as well as that of the various other sections, should be done as indicated in Fig. 38. A $\frac{1}{8}$-inch bead should be run on the edges of the vertical and horizontal members, round the drawer panels, the beads being mitred at the angles. An intermediate longitudinal rail should be introduced behind the drawers, as at *a* in *A* and at *a'* in *B*, Fig. 37, so as to compensate for the loss of strength in the front rail. The top should be made of $6'' \times 1\frac{3}{8}''$ clear, well-seasoned pine, heart stock, the edges being carefully jointed and dowelled with $\frac{7}{16}$-inch hardwood pins at 7-inch centres.

89. At *A*, Fig. 37, is shown a transverse section, taken near the end of the table, so as to show both the drawer in its pocket and the method of uniting the rails to the legs. At *b* is shown the drawer, while *c* is the lower runner, or cleat, on which the drawer slides. The upper guide, which would be placed at *d* to prevent the drawer from tilting when drawn out, is omitted,

so as to show more important details. At *e* is shown the angle plate of hardwood, which is dovetailed into the rails as shown at *e'* in *B*. This angle plate is attached to the leg by means of two lagscrews *f*, shown at *f'* in *B*, which, being drawn home, keep the shoulders of the rails in the closest contact with the legs. The dowel-pins in the top are shown at *g*. The top should not only be securely fastened to the rails, but provision must be made for its expansion and contraction ; this is effected by the use of the tongued buttons *h*, shown at *h'* in *D*. On the centre line of the table, the buttons are screwed to the top, while their tongues pass into grooves cut out of the cross-rails. These grooves must be made just the width of the button, so that the centre line of the table will not change its position. Similar buttons are placed along each side of the table, but care should be taken that their shoulders are kept clear of the rail, and that their tongues are of sufficient length, so that, under shrinkage, they will still keep in the groove. The principle involved is similar to that of a panel in a framed door, wherein the panel may *come* and *go* without straining the joints of the framework in which it is contained.

90. At *B*, Fig. 37, is shown a plan of one-half of the framework, looking downwards, in which the cross-rails *i* are dovetailed into the front and back rails *j* and into the intermediate one *a'*. These keep the long rails straight and in a fixed position. The drawers *b'* are in place, and the blocks are so set that the fronts will always be flush with the framing of the rail. At *h*, near the upper edges of the rails, are shown the grooves for the buttons. At *C* is shown a half plan of the top, looking downwards. This view shows one-half the length of the boards and the number required in the width. At *D* is shown a sectional elevation of one-half of the table taken through the framework, in which the drawers are shown at *b''*. The runners *c* are rabbeted, making the width between sinkings equal to that of the muntins *l*, in *E*, so that the pocket is kept at a uniform gauge. The upper guide strips are also omitted in this section. At *E* is shown a half elevation of the exterior. This view shows the relative position of the rail tenons *m*, which pass about $1\frac{1}{2}$ inches into the mortises

prepared for them in the legs. The tongues on the edge of the framing at *n* pass into the leg only $\frac{1}{2}$ inch. The bridge between the mortises makes the leg stronger, otherwise the cheeks of the mortises would be liable to spread and lose their grip on the tenons. At *F* is shown an end elevation, in which it will be observed that the tenons are arranged somewhat differently. Shoulders *o* are formed at the root of the tenons *m'* for the same reason as was given for the depth of *n*, in *E*.

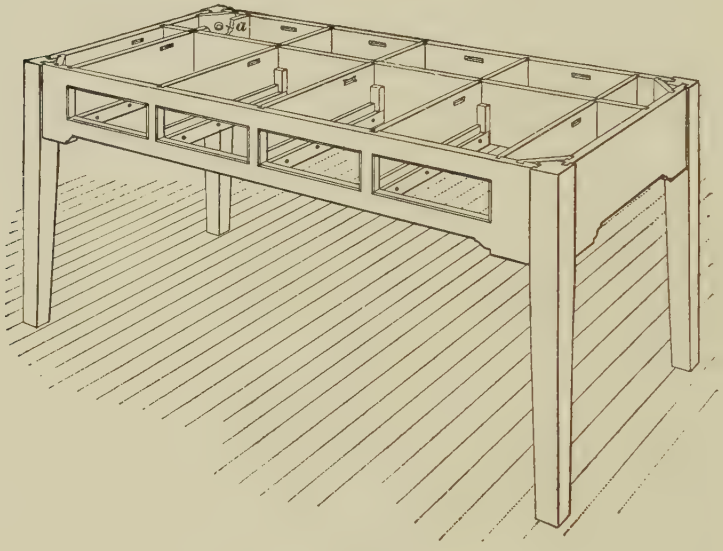


Fig. 38

91. At *G* is shown a perspective view of a drawer, with its bottom upwards. This view shows the mode of uniting the parts, whereby a firm frame is obtained, and illustrates the course followed to provide for the expansion and contraction of the bottom. The dovetails *p* are shouldered at the front, and open, or exposed, at the back, as shown at *q*. As the length of the drawer is less than its depth, the grain of the wood is run parallel with the front. By inserting glued blocks *r* adjacent to the front, close union is effected between the drawer bottom and the front. By this means, the front will not yield under hard

usage, and a close joint will always be a certainty. The back edge of the bottom has slots *s* through which are passed screws *t* into the back rail. The screws are provided with washers, so that the bottom of the drawer may move readily with change of temperature.

92. Fig. 38 shows a perspective view of the framework of the table preparatory to attaching the top, and should give a clear idea of its construction. At *a*, a portion of the cross-rail is omitted to show the angle plate and lagscrew device. All junctions should be liberally glued, and, where practicable, should be kept under clamp pressure until the glue has set. Where heavy tables over 10 feet in length are required, it is well to provide an intermediate leg on each side, so that there will be six supports instead of four, thus assuring steadiness. Tables constructed in the manner just described are well adapted for warehouse purposes. Where such tables are required to be built on the *knock-down* principle, whereby the legs can be removed and packed in the upper framing of the table top, the tenons *m*, Fig. 34, *E*, are omitted, and only the tongues *n* made to pass into grooves cut $\frac{1}{2}$ inch deep in the adjacent sides of each leg. By this method, the legs can be slipped in place and rigidly secured by the lagscrews passing through the angle plates. For small tables with narrow rails, the tongues may be dispensed with, and the rails made simply to butt against the legs.

93. Drawer Slides.—If drawers that have been used for many years are examined, it will be noticed that when they are pulled

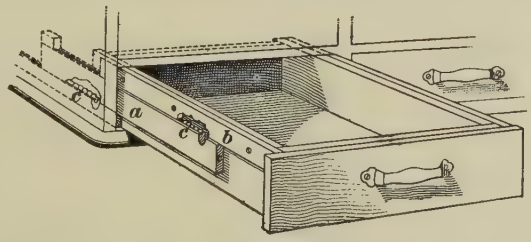


FIG. 39

out the front portion of the drawer drops, and many "up-and-down" movements have to be made before the drawer can be

replaced. This is caused by the wearing of the upper edges of the drawers toward the back, and can only be overcome by providing travelling slides, which serve as bearers, or supports, for the drawers. By this means, the drawer is supported and

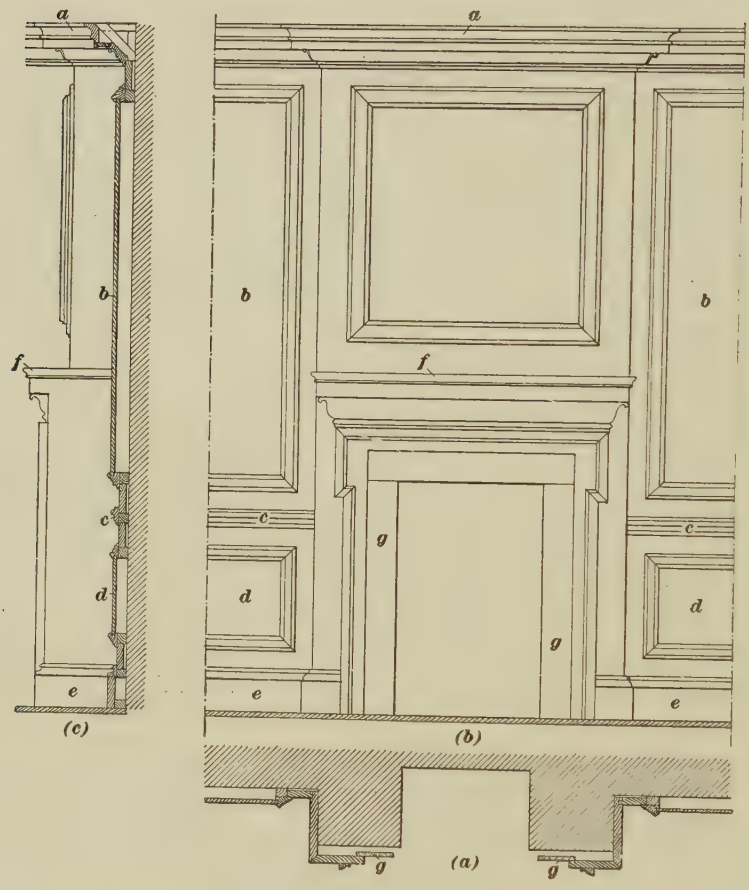


Fig. 40

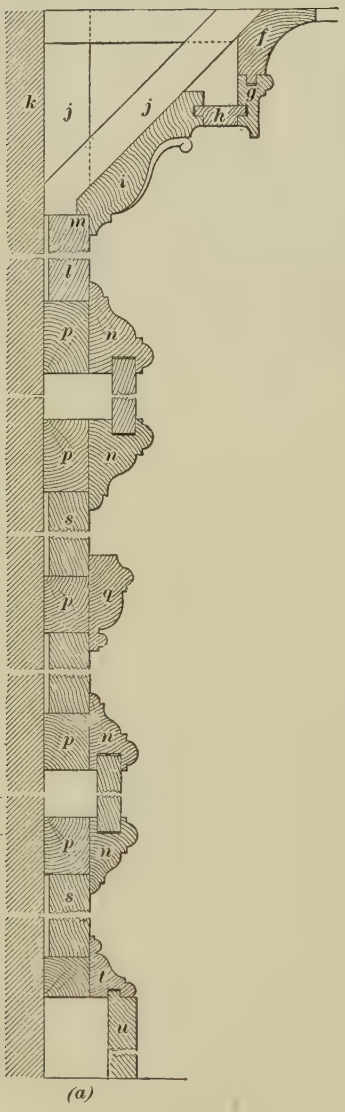
kept in a practically horizontal position, even when it is drawn out of the case to nearly its full depth. Such an arrangement is shown in Fig. 39, where *a* is the travelling slide that passes out of and in the case by operating the drawer. The weight of the

drawer is sustained by the slide *a*, on which travels a cleat *b* attached to the side of the drawer. The slide *a*, in turn, is supported by a cleat secured to the cheek of the drawer pocket. It will thus be seen that there are two planes of friction, one between the slide *a* and the drawer cleat *b*, and the other between *a* and the lower cheek cleat. This system consists in making the slides and cleats of selected hardwood $\frac{1}{2}$, $\frac{5}{8}$, or $\frac{3}{4}$ inch thick, according to the character and weight of the drawer, and grooving their upper edges with segmental grooves and inserting in these grooves a series of steel balls *c*. The grooves are made deep enough to prevent the balls from falling out when the drawer is removed for dusting, etc. It is not absolutely necessary to make the slides ball bearing, as the series of slides answers for all ordinary purposes.

94. Finishings to a Room.—In Fig. 40 (*a*) is shown the plan through a fireplace and part of the walls of a room having a wooden chimneypiece and panelled linings to the walls. At (*b*) is shown the elevation of the chimneypiece and part of the panelled linings, while at (*c*) is shown a section through the panelling and a side elevation of the chimneypiece; *a* is the cornice; *b*, the wall panelling; *c*, the dado or chair rail; *d*, the dado panel; and *e*, the skirting. At *f* is shown the mantel-board over the fireplace opening, and at *g*, the marble facing fixed as a finish against the fireplace opening. In Fig. 41 (*a*) a detail to a larger scale is shown giving the construction of the various framing. The cornice *a* in Fig. 40 (*b*) and (*c*) is here shown built up of four small pieces *f*, *g*, *h*, *i*, so as to guard against the probability of shrinkage and twisting of the wood as far as possible. The method of making the various joints between the pieces is shown, and the cornice is fixed to rough framing brackets *j*, *j*, securely fixed to the brick wall *k*. At *l* is the top rail of the wall panel *b*, Fig. 40 (*c*), which is framed up to the stiles round the panels in a manner similar to that described for wainscoting in Art. **72**. The lowest member *i* of the cornice is rabbeted over the top rail *l* to cover the joint in case of shrinkage, as shown at *m*. At *n n* are shown the mouldings forming the panel *b*, Fig. 40 (*c*), fixed to the rough grounds *p*, and the panel is shown housed or

let into the moulding *n*. At *q* is the chair or dado rail fixed to the rough ground *p*. At *n* is the moulding of the dado panel *d* shown in Fig. 40 (*b*) and (*c*), and at *s*, *s* are shown the rails round the panels. At *t* is the top member of the skirting fixed over the face piece *u*, which is constructed as described in Art. **71.** The whole of these panels and rails are fixed together in a similar manner to that described for dados, wainscots, skirtings, etc.

In Fig. 41 (*b*) is shown a detail section through the chimney-



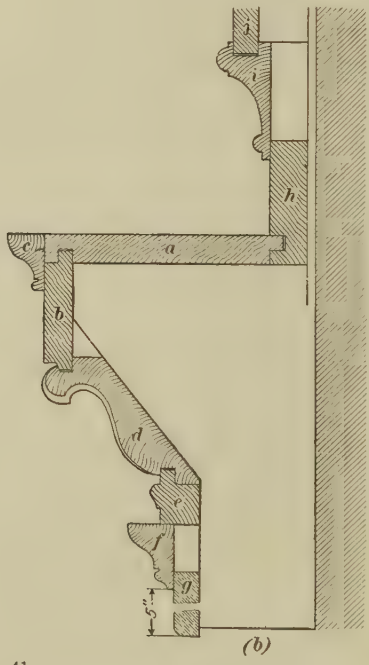


FIG. 41

piece ; *a* is the mantel-board ; *b*, the face piece ; *c*, the moulding

Fig. 42

to cover the joint between the mantel-board and face piece; *d*, the moulded and carved cornice member, with the lowest member of the cornice at *e*; *f* is the moulding mitred round the fireplace opening as shown in Fig. 40 (*b*); and *g* is the marble slip to finish the opening next to the wooden mantelpiece. At *h* is shown the lower rail of the panelling over the fireplace; *i* is the panel moulding, and *j* the panel let into it.

In Fig. 42 is shown a general view of the fireplace and panelling, which is given in detail in Figs. 40 and 41, and gives a good idea of how the details given in a geometrical working drawing actually appear in execution.

STAIR BUILDING

CONSTRUCTION OF STAIRCASES

DEFINITIONS AND CLASSIFICATION

1. Stair building grew out of the necessity of securing an easy and safe passage from one level, or floor, to another. In its inception, therefore, this passage might be regarded as an inclined plane that connects two horizontal planes and is provided with a series of equal risers, or steps, for the purpose of giving a sufficient footing to facilitate travel. In the design of staircases, the most important consideration is to arrange them so as to afford the greatest ease of communication to the stories with which they connect. Care should be taken to allow proper headroom for ascending and descending, and the treads and risers should be arranged to permit easy travel. The proper width also has much to do with the appearance; in private houses, the staircase should never be less than 2 feet 8 inches wide, and in public buildings never less than 4 feet 6 inches.

In studying the plan and treatment of a staircase, the architect should consider its adaptability for the building in which it is to be placed, its proposed position, the weight likely to come on it, the width to accommodate probable travel, and, especially, the ease of travel. It is not enough, as is sometimes done, to roughly calculate the treads and risers and sketch on the winders, leaving the builder to make the best he can of the conditions. The importance of proper arrangement is evident when it is considered that staircases are seen by everyone, their convenience and beauty being readily appreciated and their faults and defects instantly detected.

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The construction of wooden staircases is considered the highest branch of joinery, for more care and knowledge are required in their planning, more ingenuity in setting them out, and more skilful workmanship in their execution than in any other work about a building.

2. Materials Used.—The materials most commonly used in the construction of staircases are stone, iron, wood, concrete, and marble, and their selection depends on the situation of the staircase and the use to which it is to be put. If the staircase is to be built on the outside of a building, stone is preferable, owing to its weathering qualities. If the staircase is to be erected on the inside of a building designed to be fire-resisting, iron, hard wood, or concrete, is generally employed, because of its non-inflammable qualities. Either iron or stone is preferable to wood when used in public buildings where the amount of traffic requires extra wearing qualities. Wood, however, is the material commonly used, especially in private buildings where no heavy traffic occurs. This Section is restricted to the description of the construction of wooden staircases.

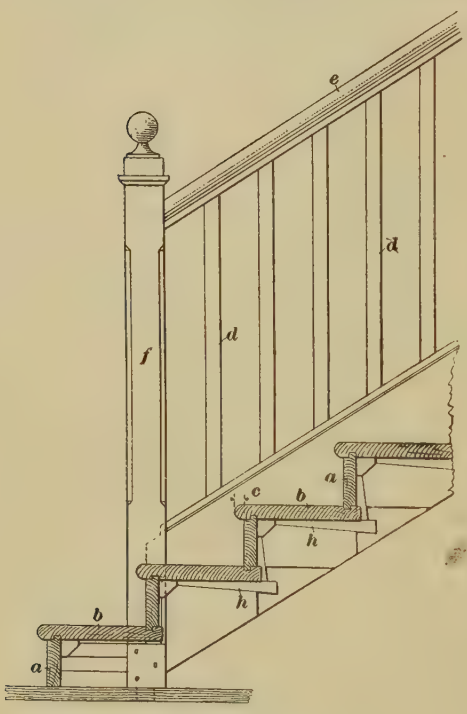


FIG. 1

3. Technical Terms.—In stair building, a *riser* and *tread* together are termed a step, the riser *a*, Fig. 1, being the upright

portion that supports the **tread** *b*, or horizontal part, on which the foot is placed. The **nosing** *c* is the projection of the tread beyond the face of the riser. At *d* is shown the **balustrade**; a series of balusters support the hand rail *e*, which is housed in the newel *f*. Wedges *h*, *h* are used to tighten the treads and risers after they are housed into the string. Where the risers are parallel with each other on plan, thus forming straight steps, the steps are called **fliers**, but where the risers radiate or taper on plan the steps are called **winders**.

The term **flight** designates a succession of steps between one starting point and the starting point next above it. The spaces wider than steps, which constitute resting places between the flights, or which are the terminations of the staircase, are termed **landings**. If the landing is square and occupies half the width of the staircase, it is called a **quarter-space landing**, but when it takes in the full width of the staircase it is called a **half-space landing**. The space required for landings is sometimes filled in by winders; this is especially the case in geometrical staircases and those in which the space is limited. Where space is unlimited, a half-space landing should be adopted, but where there is not room to allow this kind of landing, a quarter space is preferable to winders, as the latter should never be put in a staircase when they can be avoided.

When the lower step of a flight has its outer end in the form of a horizontal spiral scroll, it is termed a **curtail step**. When the outer end of the lower step is rounded to a semicircle, it is a **bull-nose step**. Where steps have an outward curve, they are called **swelled steps**; this form is generally used when the front string is curved out at the starting of the staircase. If, in ascending a staircase, the hand rail is on the right-hand side, the staircase is called a **right-hand staircase**. If the hand rail is on the left-hand side, the staircase is called a **left-hand staircase**.

CLASSIFICATION OF STAIRCASES

4. Staircases are known as *dog-legged*, *open newel*, and *geometrical*. A **dog-legged staircase** has no well hole, and the face string of the upper flight is vertically over that of the lower one. A well

hole is the vertical clear space between flights when the strings of the return or upper flights are not in the same vertical plane as the lower ones. The objection to dog-legged staircases is that the hand rail is not continuous, but strikes the soffit of the upper flight.

Where newels are placed at the angles of the well hole, the staircase is termed an **open-newel staircase,** but when the string is continued unobstructed by newels in a curve round the winders, the string is said to be *wreathed,* and the staircase is designated as **geometrical.** The wreathed portion of a string may be described as being inclined in elevation and curved on plan.

5. Methods of Construction.—When staircases are classified with relation to the methods of construction, there are two systems: the first consists in the use of rough timbers, or *carriages,* cut to the angle of intersection between the treads and

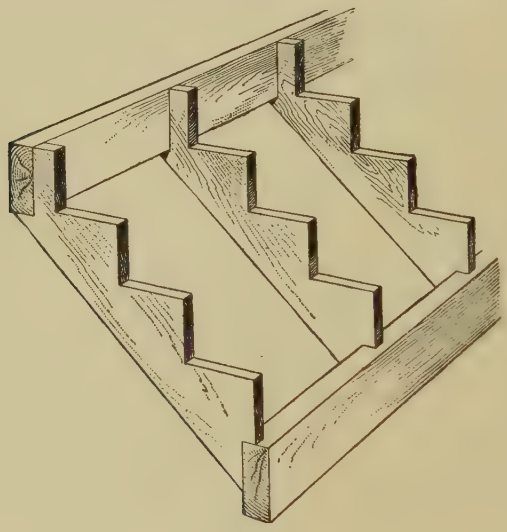


Fig. 2

risers, as shown in Fig. 2; the other, which is more generally used, has the treads and risers tongued, or *housed,* from $\frac{1}{4}$ to $\frac{3}{8}$ inch, into the grooved strings. In the first case the treads and risers are nailed on to the carriages, and, where they intersect with the

wall, a board of the same thickness as the baseboard connecting with the staircase is *scribed*, or cut, to the required outline, so as to fit closely the angles of treads and risers ; this board runs the full length of the staircase, forming what is termed the **wall string.** In favour of this method of construction are its simplicity and strength. Against its adoption may be adduced the great difficulty of satisfactorily scribing the wall strings, and even when this is successfully done, the staircase is likely, in time, through shrinkage and jarring, to show imperfections.

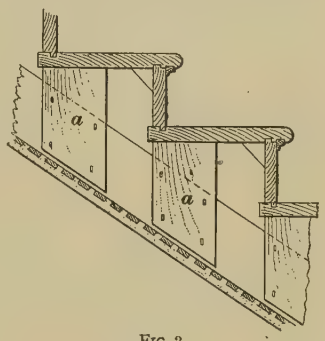


FIG. 3

The carriages for the second form of construction of staircases are not cut to the angle of treads and risers, as is the case in the first method, but are simply straight scantlings of sufficient strength to support the staircase and its probable load. Rough brackets, nailed on the sides of these scantlings, fit tightly under each tread and against the riser, as shown at *a*, Fig. 3.

6. Varieties of Strings.—In some cases, where the treads and risers are enclosed in strings, the wall string only is grooved to receive the treads and risers, the outer string being cut square to receive the tread and mitred to receive the riser. When thus prepared, the front string is termed a **cut-and-mitred,** or **open, string,** and the wall string is termed a **housed string.** Occasionally, both the wall and the outer strings are housed, in which case the outer string is said to be a **close string.** Geometrical staircases are seldom thus constructed, the method being mostly confined to dog-legged and open-newel staircases.

In geometrical staircases the front string is cut and mitred so as to meet the conditions arising from the wreathed portion of the string and hand rail, which are assumed to be parallel with each other in the same vertical plane. The hand rail in this case is supported by the balusters and starting newel instead of by newels, and the cut-and-mitred string affords a

substantial footing for the balusters, which are dovetailed, glued, and nailed to the ends of the treads, the nosing and moulding of the treads being returned their full width on the face of the string. Stairs thus constructed are said to have *nosed-and-mitred mouldings*, and when ornamental brackets are placed along the front string below the nosing, the string is known as a **bracketed string.**

DETAILS OF CONSTRUCTION

SETTING OUT STAIRS

7. Stair Measurements.—The stair builder should verify all measurements at the building, the distance from floor to floor especially, as the heights of ceilings seldom measure exactly what they are figured on the drawings, varying from 1 to 2 inches either way. The stair builder measures off this height on a rod, called a **story rod,** and divides it into spaces corresponding in number with the risers in the staircase. If the measurements given on the drawing for the height of stories are trusted and the strings are cut to fit the height thus taken,

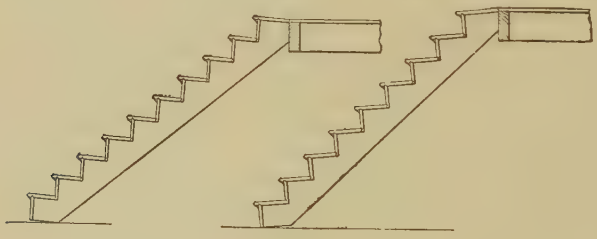


FIG. 4

staircases resembling those shown in Fig. 4 may result. It is important that all risers should have a uniform height, for any change, although not apparent to the eye, will be discovered by travelling up or down. For instance, take a staircase having two flights, with a landing between, in which the risers of the upper flight are $\frac{1}{2}$ inch higher than those below. A person ascending this staircase rapidly will be checked, as it were, as soon as the higher risers are reached, and will be likely to trip.

8. **Height of Risers.**—Care should be exercised in setting out the risers that a staircase is obtained that will have steps of convenient height. Experience teaches that a rise of between 6 and 8 inches is the limit of easy stepping; therefore, to find the number of risers required, the total height of the story rod should be divided by either one of these figures, according to circumstances; by 8, only if space available is very limited. Having in this manner ascertained the number needed, divide the height of the story rod by the number of risers; the quotient will be the exact height of each riser.

9. **Pitch of Stairs.**—The next step is to ascertain the width of the treads, which when settled will give the angle of inclination, or pitch of the flight, not forgetting the rules of proportion between treads and risers. Owing to the landing not being counted as a tread, the number of treads in each flight is one less than the number of risers. There are several rules for ascertaining the proportion that should exist between a tread and a riser for staircases, and that determines not only the appearance of the staircase, but also the ease with which it may be travelled. Of the three rules given the first is the simplest and the one generally preferred.

Rule I.—*Let the product of the tread and riser equal the number 66.*

Assume that the riser is 6 inches high, then the width of the tread will be $66 \div 6 = 11$ inches. In the same way, the width of tread may be assumed and the height of the riser found.

Rule II.—*To any given height of riser, in inches, add a number that will make the sum equal 12; double the number added, and the result will be the width of the tread, in inches.*

Assume that the height of a riser is 7 inches; then $7 + 5 = 12$, and $5 \times 2 = 10$, the width of the tread, in inches.

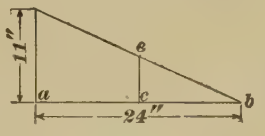


FIG. 5

Rule III.—*Draw a right triangle, as shown in Fig. 5, with a base of 24 inches and altitude of 11 inches. Mark the width of tread from* a *on line* a b, *as* a c; *at* c *erect a*

perpendicular, cutting the hypotenuse at e. *Then* c e *indicates the riser.*

10. Headroom.—In trimming openings in floors for staircases, the cross-beams, which are called *trimmers*, should be so placed as to allow sufficient headroom to meet all probable requirements of a staircase. The trimmer, which determines the headroom, should be placed so as to secure 7 feet of headroom from the tread vertically beneath it. A careful drawing of the section of the staircase will accurately determine this point. Where a number of winders are placed at the bottom of a staircase, and the risers thereby stand one above the other at the centre from which they radiate, a considerable rise is produced at the commencement of the flight, the amount depending on the number of winders. In such cases the trimmer is placed over the extreme end of the staircase and thus ceases to be a factor in the headroom. This applies especially to *boxed staircases*, which are enclosed between partitions.

CONSTRUCTION OF STRINGS

11. Setting Out.—A straight string is set out by means of a pitch board, which is shown in Fig. 6 (*a*). This board should be made of thin wood, the grain running parallel with the hypotenuse so that the effects of shrinkage will be the least possible. The base is cut to equal the tread, and the perpendicular to equal the riser. In (*b*) is shown the string as marker out for the steps. The dotted line *a b* is drawn at a sufficient distance from the edge to permit the lower edges of the riser and tread just to intersect on the line of the under side of the string, as shown at *d* ; and on the line *a b*, distances equal to the slope length of the pitch board are set out with dividers. The pitch board may then be applied as indicated, and its outline marked on the side of the string.

Templates, as shown in (*c*), should be made for the treads, risers, and wedges, care being taken that the pitches are alike, so that wedges of the same shape can be used. The lines *a d c b* show the section of the tread, and *a e f* shows the shape of

the wedge. When applied to the string, the tread-and-riser templates should have their outer edges coincide with the lines

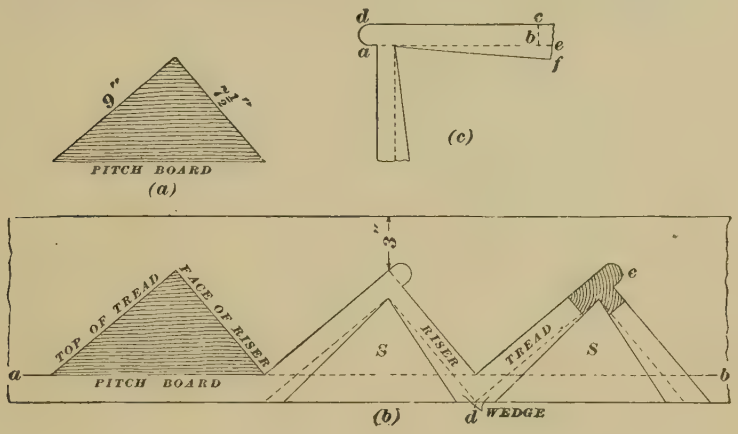


Fig. 6

made from the pitch board, giving the outline shown at *S*, Fig. 6 (*b*).

12. To form the housing, holes are bored in the strings adjacent to the nosing of the tread, as at *c*, Fig. 6 (*b*), and that

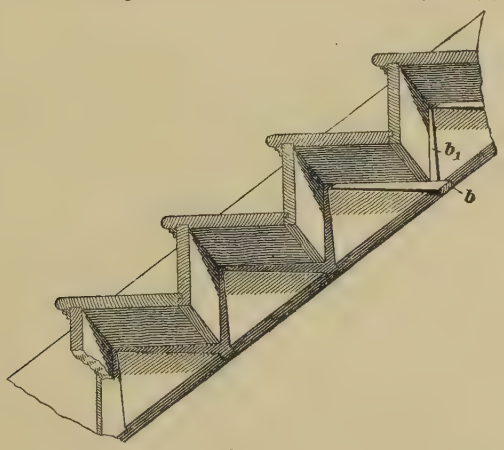


Fig. 7

portion is removed by means of a chisel. The lines of the templates may then be cut to the depth of the groove with a

saw, and the material removed with a router plane. Such a string is shown in Fig. 7 with the exception that the under edge is kept somewhat lower than the point *d*, Fig. 6 (*b*), and is preferable to the latter method in that the wedges are well supported at their outer ends. If the staircase will allow the insertion of the assembled parts, the treads and risers are attached to the strings, wedged and glued into the housing, and the whole taken bodily to its place in the building. The wedges are shown in place at *b* and b_1, Fig. 7.

13. The wall string, as shown in Fig. 8 and also the front string, if a close one, are each grooved as already explained, the depth depending on the thickness of the string. Two or more carriage timbers are used in the width of the staircase, the number, depth, and thickness depending on the width of the staircase and the load to be carried. The outer string, as shown

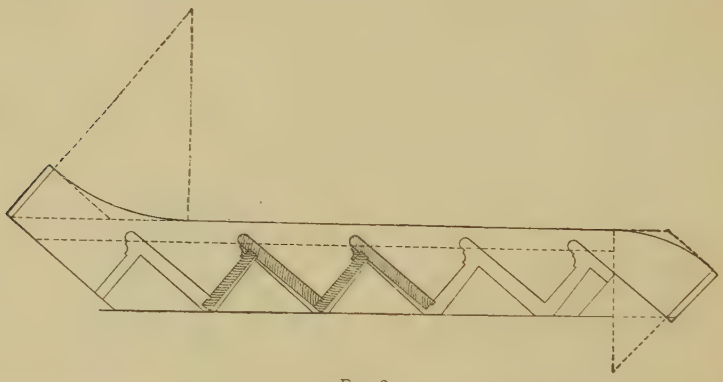


Fig. 8

in Fig. 9 (*a*) is well nailed to the outer carriage *a*, while the other carriages, if any, are rough bracketed up to the under side of the treads and nailed as shown in Fig. 3. A furring strip, or strap, to receive the laths is nailed to the wall in line with the lower edge of the carriage timbers. The prepared mortised wall string is nailed to the wall to square properly with the previously set carriage timber and front string.

The following is a simple method of finding the bevel cuts for the stair string shown in Fig. 9 (*a*). The bevel is applied to the

upper edge of the uncut string, so that only one cut is necessary. The cut fits a 45° mitre on the riser. On the outside face of the

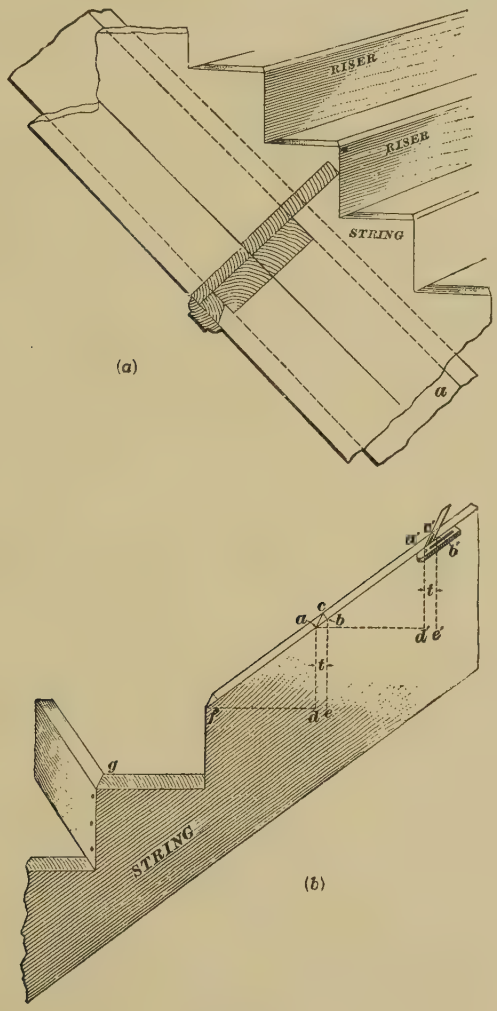


FIG. 9

string shown in Fig. 9 (*b*), mark cuts for treads and risers, as *f d a d' a'*. Now, parallel with *a d* and at a distance *t* from *a d* equal to the thickness of the string, draw the line *b e*. At point *b*

draw the line $b\,c$ square across the upper edge of the string, and connect c and a. Then, $b\,a\,c$ is the bevel angle required. At a' is shown a bevel applied to the upper edge to mark off the line $a\,c$, while at f is shown the appearance of the mitre after cutting. A riser mitred to the string is shown at g.

14. Scribing Wall Strings.—When the treads and risers are supported by rough-cut carriages, it becomes necessary to cut a wall string that will fit round the steps and make a finish with the wall. In Fig. 10 is shown a method of *scribing* a wall string. The string is represented as being laid with one edge on the line of the nosings, and the instrument to be used is shown in position. The hardwood or iron bar $b\,h$ has a hook on the lower end, which projects sufficiently to enable the bar to clear the nosing when the point b is touching the face of the riser. The bar $b\,h$ is placed

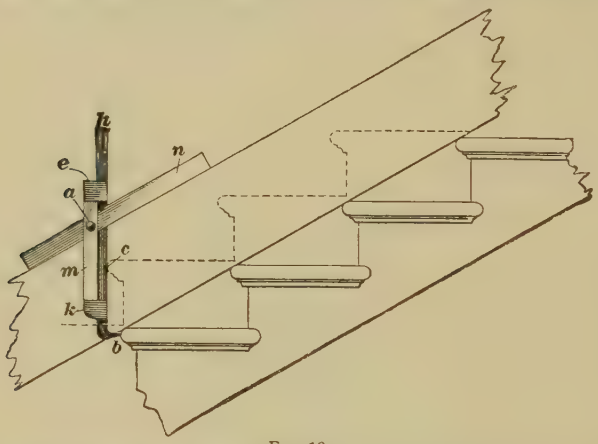


FIG. 10

against the guide m, being loosely bound to it by the metal straps e and k. The strip n is fastened to m by a bolt a, which can be tightened so as to preserve the bevel. A small nick is made in the sliding bar $b\,h$ at c, so that $b\,c$ is the height of a riser. When the point b is on the edge of the nosing, the nick c gives the position of the corresponding point on the wall string, which may be marked with a steel point, or pencil. Other points may be found in a similar manner, and the outline to which the wall string is to be cut can then be drawn.

CONSTRUCTION OF STEPS

15. Joints Between Treads and Risers.—In constructing stairs, the upper edge of the riser may be tongued into a groove in the under side of the tread, as shown at *a*, Fig. 11 (*a*), instead of letting the whole thickness of the riser into the tread, as shown at *b*, view (*b*). The lower edge of the riser may also be tongued into a groove in the upper surface of the tread beneath it, as shown at *b*, view (*a*), in which case the tread will have to be nailed up into the riser as at *c*. Another method is that shown at *a*, view (*b*), but this is not so good, for the tongue on the end of the tread is liable to be broken or split if the joint becomes at all loose with the continual traffic on the tread. The finished treads and risers are glued together, being clamped with handscrews until the glue has set. From two to four well-fitted blocks are then glued and nailed to the internal angle of the tread and riser, as shown at *a* in (*a*) and *b* in (*b*). In Fig. 11 (*b*) is also shown the dovetails for inserting the balusters.

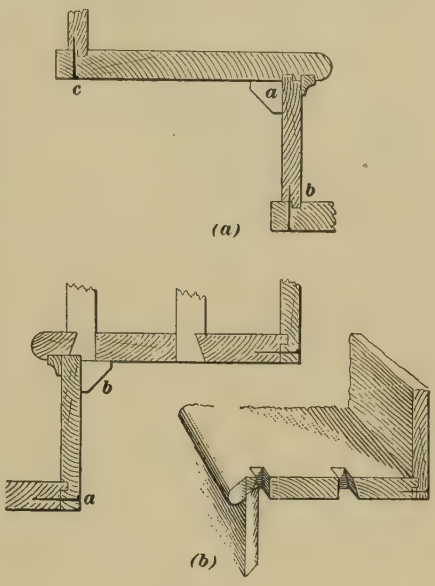


FIG. 11

16. Bull-Nose Steps.—A form of step that is much used is illustrated in Fig. 12. A solid or built-up block of wood is sawn to the shape shown at *e*, and the riser is sawn out as indicated, leaving a veneer to cover the face of the block. The end *b* is firmly fastened to the solid block with screws. At *a*, a square hole is left the full depth of the riser, into which wedges are driven from each end, as suggested at *d*. The back of the veneer

is covered with glue, and as the wedges are driven home it is clamped firmly against the face of the block. The newel is generally set on top of this step, and housed into it, as indicated by the dotted lines. The second riser may be placed in line with the middle of the newel, as indicated at *c*, or in any other position desired.

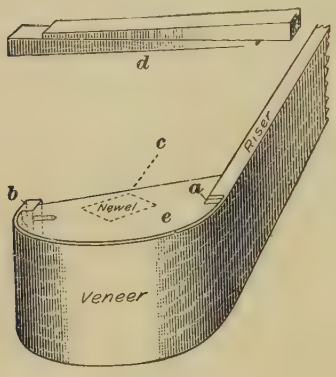


Fig. 12

17. Curved Risers. — Where risers are curved, they should be made of solid wood, or of curved strips of seasoned wood glued solidly together. Frequently, however, seasoned wood in pieces large enough to make a solid curved riser cannot be secured. In such cases it becomes necessary to bend pieces of 1-inch board; this may be done by *kerfing* or forming cuts along their surface with a saw, as shown in Fig. 13. The method of finding the distance between kerfs for a curve of given radius is as follows:

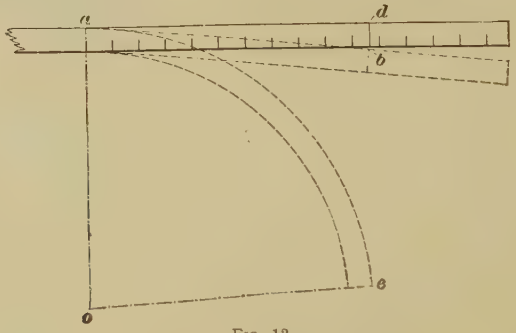


Fig. 13

Cut one kerf, as at *a*, Fig. 13, then, marking the distance *a d* equal to the radius *a o* of the curve to which the piece is to be bent, bend the board to position *a b* until the saw kerf is closed, as shown. The distance *d b* is the distance between kerfs, which, if continued, will shape the board to the curve *a e*. All the kerfs must be of the same width and depth.

18. Landings.—Where the staircases of a building are of considerable length and are straight on plan, it is best to break the flight by a landing, as shown in Fig. 14, where trimming joists *b*, *b* are securely fixed into the wall at one end *a*, *a*. These trimming joists support the ends of the carriages of both flights, as shown at *c*, *c*, and have filled in between them ordinary bearers or joists *d d* on which floor boards are laid to form the landing. In a brick wall the ends of the trimming joists *a*, *a* should be set in at least 9 inches, with slip keys tightly wedged between the bricks and the top of the timbers. In framed partitions they should be railed to the studs. A flight terminating in a landing should not contain more than twelve steps. A perspective sketch of the landing is shown in Fig. 15.

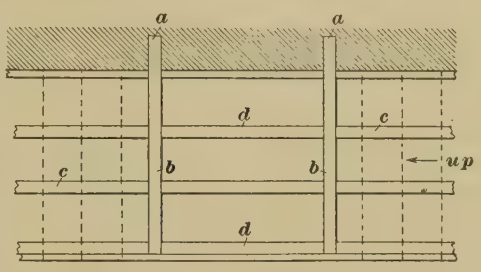


FIG. 14

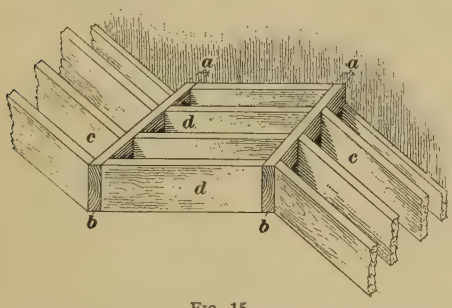


FIG. 15

CONSTRUCTION OF HAND RAILS AND BALUSTRADES

19. Newels.—Newel posts, or newels, are used to support the hand rail, and are made either of solid material and turned, or are built up box-like, in which case they are called **box newels.** They vary in design, form, and size, some, especially the one placed at the bottom of the staircase, called the **starting newel,** often being elaborated with panels and carving. The newel is variously fixed in its relation to the steps adjoining ; in ordinary cases it is placed on the floor, and when so placed its centre should be in line with the centre of the first riser. Where space

is limited at the bottom of a staircase, the newel may be placed on top of the first step, or even on top of the second or third step, but in each case it should be so placed as to have the centre of the riser in line with the newel centre, and the steps outside rounded and returned into the string. The end of the latter is inserted into a prepared mortise in the centre of the newel.

The **angle newels** on the landings are sometimes smaller in size and are often treated more simply than the starting newels. The same rule applies to their relation to the risers ; namely, that the centre of the riser should be in line with the centre of the newel. Working from centres in stair-building construction is almost a maxim. The centre of the hand rail is to be in the centre of the newel ; so, also, is the centre of the string. The centre of the baluster is to be in the centre of both the string and the hand rail, and, as stated before, the centre of the riser adjoining the newel is to be placed at the centre of the latter.

20. Balusters.—Balusters, sometimes called banisters, are small columns or supports, often turned, that are set vertically on the ends of treads or on the string, forming an ornamental guard and supporting the hand rail. When the outer string is closed, or housed, the balusters are fixed to the string instead of to the treads, a grooved moulding, called a *cap*, being prepared to receive them. The lower ends of the balusters in this case are cut to the pitch of the staircase, and the top is either cut to the same pitch as the rail or is mortised into it. This applies to balusters having square ends. Frequently, they are made square or round at the bottom and turned to a spindle shape at the top, being then termed **pin balusters.** Balusters with square bases are preferable to those with round bases, as the bearing surface and resistance to movement of a square base are almost double that of a round base. Holes are bored about an inch deep into the under side of the rail to receive the balusters, and the lower ends of the balusters are either cut to the pitch of the staircase or are dovetailed to the ends of the treads, depending on whether the string is housed or cut and mitred.

In ordinary staircases, two balusters are placed on each tread, but in the better class of staircases the number is increased,

thereby adding to the beauty and strength of the balustrade and to the general appearance of the staircase. The two balusters on a tread are placed half the width of a tread apart between centres, the short one standing close to the nosing and the long one being placed midway between the adjacent nosing baluster. The usual height of pin balusters is either 2 feet 4 inches or 2 feet 8 inches, of which 1 inch is allowed at each end for insertion into the rail and the tread.

In some staircases the space between the balusters is filled in with flat-cut balusters of various designs, or is panelled. In either case the number of balusters is reduced to one for each tread, ordinarily placed over the face of each riser, thus leaving the full width of the tread, less the thickness of one baluster, for the decorative cut balusters or panels.

21. Hand Rails.—Hand rails may be made of metal, but are usually made of wood. When in long lengths, they may be stiffened with an *iron core ;* this is a flat strip of iron, $\frac{1}{4}$ or $\frac{3}{8}$ inch thick and $1\frac{1}{2}$ or 2 inches wide, placed in a groove on the under side of the rail. Holes are drilled through this to permit the balusters to be fixed to the rail. Hand rails are made in various shapes and sizes. That shown in Fig. 16 (*a*) is known as the plain deal *mopstick ;* it is used only in the cheapest kind of work. That shown in (*b*) is described as *rounded ;* it is

Fig. 16

generally used in warehouses and factories, or where rough wear may be expected. Those shown in (*c*), (*d*), (*e*) are made in hardwood, moulded more or less elaborately and polished ; they are used in the better class of work. That shown in (*f*) is known as the *toad's back ;* it is used for the best class of work. In very large staircases it is frequently built up in several pieces, fixed together with grooves, tongues, and glue. The grooves under (*c*), (*d*), (*e*), and (*f*) are recesses for the wrought-iron core. Hand rails are joined by butt joints which are brought together and held in position by screws and nuts concealed in a

chase in the centre of the rail. The nuts have holes in the faces and can be tightened by means of a bradawl or what is called a *pinhole spanner.*

The development of hand rails, which involves complex geometrical problems, is not within the province of the architect or builder, though a few remarks regarding their construction are pertinent. Except where the rail is placed over winders, whether at the bottom of the staircase or round the well hole, it should be set parallel with the line of nosings. The pitch will be greater over the winders than over the straight flight, and as this determines the height of the rail, it follows that any addition to the pitch over the winders will require more height for the wreath. This additional height, however, should never be such as to cause an unsightly crippled appearance where the curve of the wreath intersects with the straight rail. In staircase construction, each baluster should be set vertically and be glued solidly and nailed to the hand rail, so that when tested there shall be no noise, which would indicate the presence of loose balusters through imperfect fitting, poor gluing, or carelessness in nailing.

22. Ramps and Easings.—In an open-newel staircase the hand rails usually meet the newels one above the other. To bring the hand rails to the same level, they must be **ramped,**

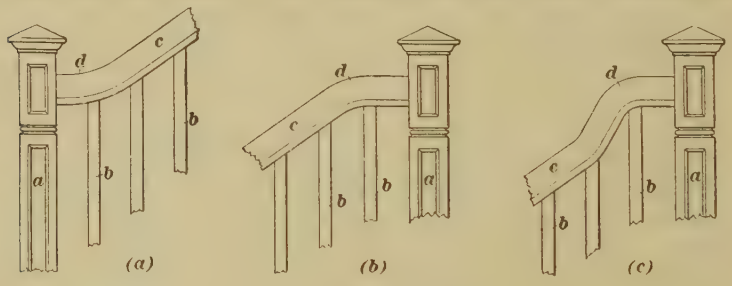


Fig. 17

as shown in Fig. 17 (*a*), where *a* is the newel, *b* the balusters, and *c* the hand rail ramped at *d*. The corresponding curve at the top of a flight is known as a **knee** and is shown at *d* in Fig. 17 (*b*), the other letters corresponding with those in (*a*). Sometimes

hand rails are ramped and *kneed*; when the knee is convex, the combined curve is called a **swan neck** or a **goose neck**, as shown at *d* in Fig. 17 (*c*), the other letters corresponding with those in (*a*). The lower ends of hand rails abutting against the newels may be either straight or curved. When curved, the rail is said to be **eased**, and the curved portion of the rail is called the **easing**. This arrangement, however, requires the newel to be somewhat longer.

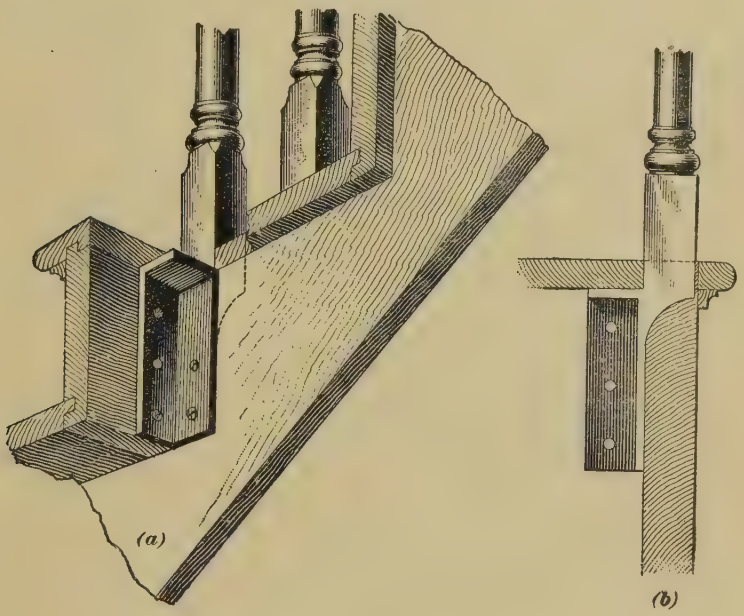


FIG. 18

Where the straight rail enters the newel at the bottom of a flight without a ramp, the newel may be made from 4 to 6 inches shorter than would otherwise be possible, the reduced height often being a matter that should be taken into account. Where such is not the case, the hand rail may be ramped, so as to enter the newel in a plane perpendicular to it, and the angle of intersection between the raised level portion and the inclined plane of the straight rail is gracefully eased. This last method is the one most commonly adopted, owing to its better appearance.

23. Stiffening Hand Rails.—Continuous hand rails are sometimes provided with an iron core let into a groove in the under side of the rail, which should extend the whole length of the rail. Instead of this core, an iron baluster of the same section as the wooden ones, and painted to resemble them, is often placed at each end of the wreath. Fig. 18 (*a*) is a perspective sketch of the base of such a baluster, which is formed into a flanged connection and attached to the riser and to the string by screws; (*b*) is a side elevation of the base and its relative position with reference to the face string.

MISCELLANEOUS DETAILS

24. Mouldings.—All base and string mouldings should be worked out of solid wood. Work that is to be bent is generally stronger when laminated, as shown in Fig. 19, but for mouldings this method cannot always be used, since the joints will show no matter how well the work is done. This is particularly true of hardwoods. If the work is to be painted, however, this method is not objectionable.

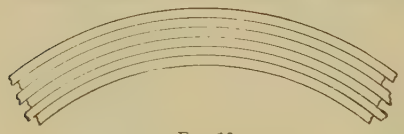


FIG. 19

25. Erection.—If the staircase is put up against the wall immediately after the first coat of plaster has been put on, the finished parts must be well covered to protect them from damage. Rough boards should also be placed on the treads and allowed to remain there until the interior woodwork and plastering are completed. The covering, however, should be fixed in such a manner that enough of it can be easily removed to permit the erection of the hand rail and balusters. When the stairs are set in place, they should be carefully inspected to ascertain if any of them are cut short and pieced, if any of the wedges are improperly glued, or if the nailing of treads and risers is omitted. The staircase should make no creaking noise when a person ascends or descends; even a slight creaking is sure to grow louder in time, and thus be a lasting reminder of

defective work. Creaking is generally due to defective gluing, nailing, wedging, or to the use of unseasoned stuff in the rough carriages and brackets, or in the finished material.

GENERAL STAIRCASE DESIGN

ORDINARY FORMS

26. Step Ladders.—One of the simplest forms of staircases in use is a fixed or movable **step ladder,** such as is sometimes built from an attic floor to the roof, and shown in Fig. 20, where (*a*) is a plan, and (*b*) a section. The top step should always have an increased width, if it is not at the level of a landing, and the sides of the ladder should be at least 6 inches wide by $1\frac{1}{8}$ inches thick. The steps are housed, or gained into the sides not less than $\frac{3}{8}$ inch, and are securely nailed or screwed thereto. As shown in the figure, this ladder rises 8 feet, or 96 inches, which, divided by 10, the number of steps, gives $9\frac{3}{5}$ inches for each rise; in this case the risers are omitted. The horizontal distance from the face of the landing beam to the bottom of the ladder equals 3 feet 7 inches. This distance, less 3 inches for additional width of top step, leaves 3 feet 4 inches, or 40 inches, which, divided by 10, the number of treads, gives 4 inches as the width of each tread from its nosing to a vertical line dropped from the nosing above.

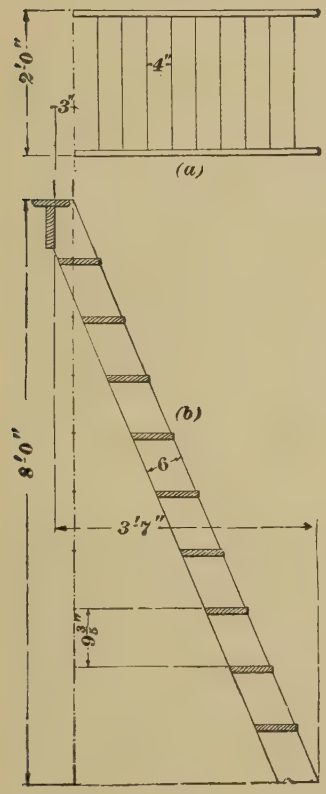


FIG. 20

27. Plank Staircase.—In Fig. 21 (*a*) and (*b*) are shown the plan and sectional elevation of a strong **plank staircase**, such as may be required for a shop or factory; *a* and *b* are newels, 6 inches square, to which $3'' \times 1\frac{1}{2}''$ hand rails *c* and *d* are fastened and braced with one or more uprights *e*. In (*c*) and (*d*) methods of forming the hand rail are shown. As shown in (*b*), hardwood treads *g*, 2 inches thick, are mortised 1 inch into 3-inch timber strings, 9 inches wide, tightly fitted into the mortises, and well spiked, but not wedged. The soffit may be ceiled with matched lining, as indicated at *f* in the illustration.

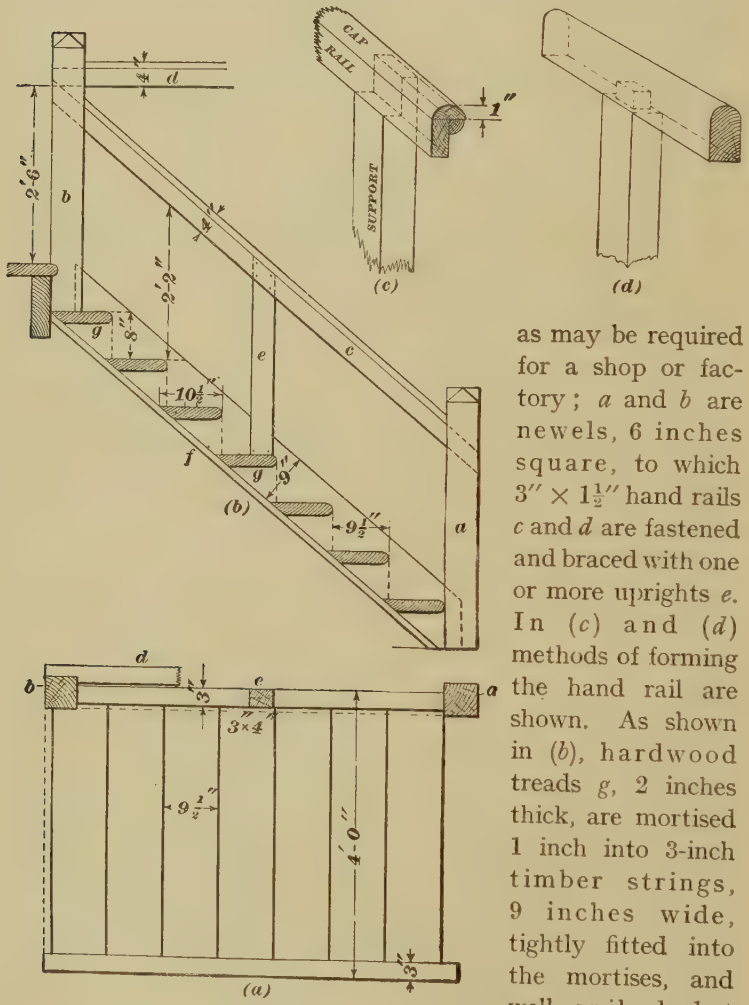


FIG. 21

28. Newel Staircases.—In Fig. 22 is shown a part plan of a quarter-landing open-string staircase with 4-inch square newels framed in the angles, the hand rails and strings making straight connections with the newels, as shown in Fig. 23. The position

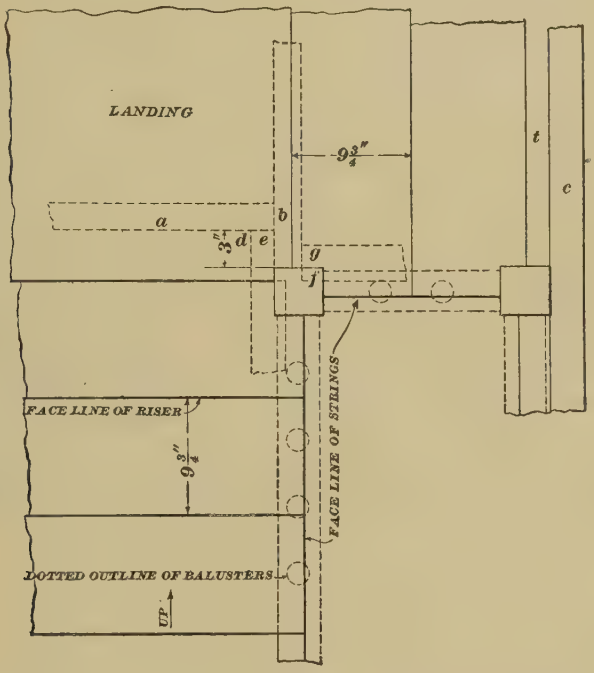


FIG. 22

of the landing beams, or bearers, *a*, *b*, Fig. 22, should be such that a good bearing is secured for the carriage timbers at *d*, *e* and *f*, *g*. The landing beam *b* should be brought forwards to give a support of about $\frac{3}{4}$ inch for the newel.

The sectional elevation shown in Fig. 23 is projected from the plan and shows the relative positions of the newels, hand rails, balusters, and step finishings; the latter is composed of $1'' \times \frac{1}{4}''$ fillets, nosing, and scotia. The newels may be solid or they may be built up as shown in Fig. 23 (*a*), slip tongues being inserted into grooves in the sides, and the whole properly glued and blocked. The blocks are first glued to the two narrow

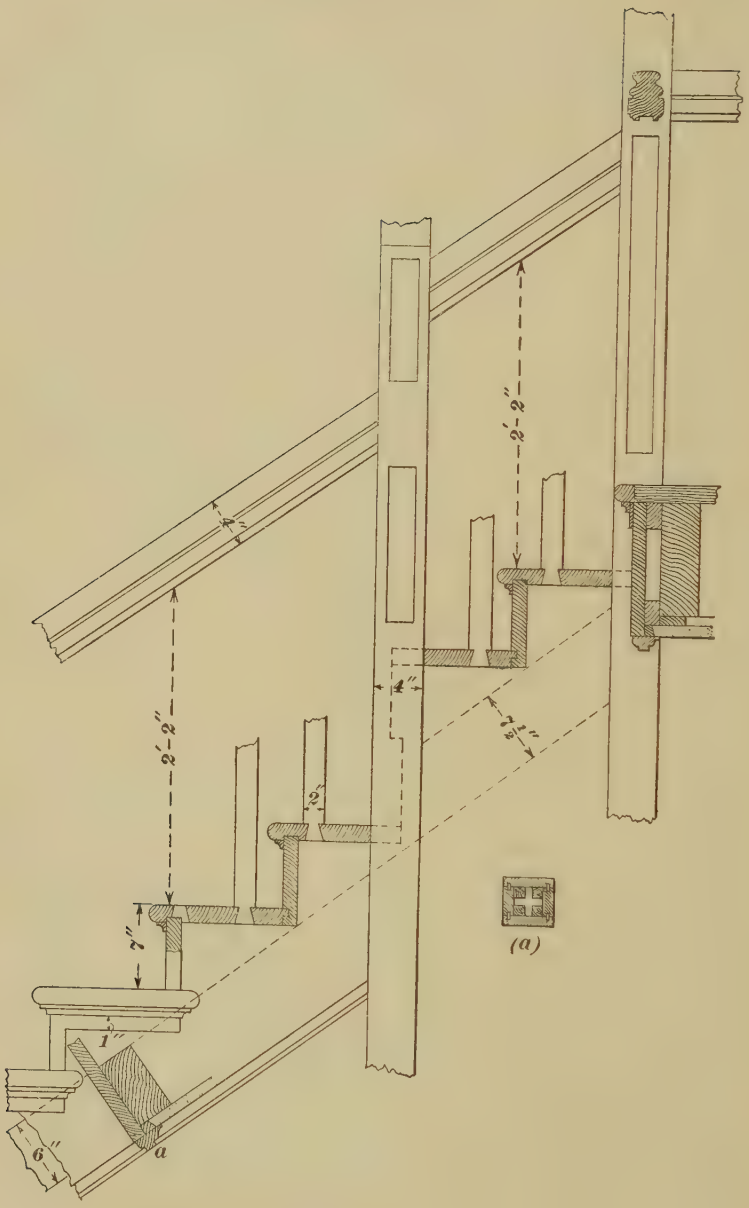


FIG. 23

sides of the newel, and when dry are planed square with the edge of these pieces. The whole is then heated in a hot box, and the blocks, edges, and slip tongues are glued and brought together with handscrews.

29. Open String.—In Fig. 24 are shown an elevation and a section of an open string, where fillets are used. At (*a*) is a portion of the string showing the step finish with fillets *a*, *a*. The lower portion of the string is relieved to form a fascia *b*, and the edge *c* is formed into a quirk bead against which the plaster finishes. While frequently adopted, this method does not give nearly so good a bond for the plaster as does the soffit mould shown at *a*, Fig. 23, in which case the edge of the string is kept square. Fig. 24 (*b*) illustrates a section of the fillet, mitring with the riser, which shows that the face string must be kept back the thickness of the fillet, in order that the latter may mitre properly with the riser. This fillet is only used to give a neat appearance to the end of the step. Cut scrolls or carved brackets, as shown at *d*, view (*a*), may be planted on to the string for the same purpose.

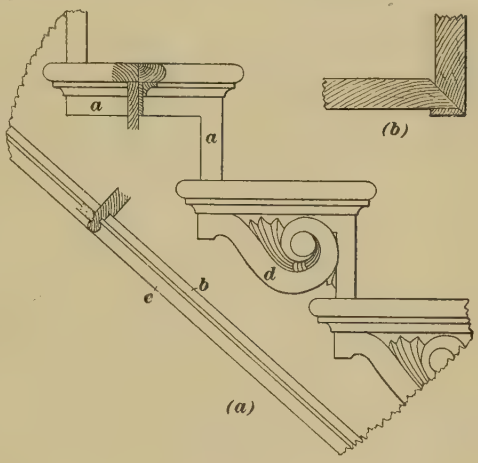


FIG. 24

30. Close Strings.—In Fig. 25 are shown a plan (*a*) and a projected elevation (*b*) of a quarter-landing staircase with four risers in the flight adjacent to the landing, close-panelled and moulded strings, 6-inch square newels, $2\frac{1}{2}$-inch turned and square-base balusters, and a $4\frac{1}{2}'' \times 4''$ fully moulded hand rail, having a ramp-and-knee, or goose-neck, connection with the newels. In the plan, *a* and *b* are the principal joists, or bearers, of the landing, and *c* is the top-landing floor joist. In drawing

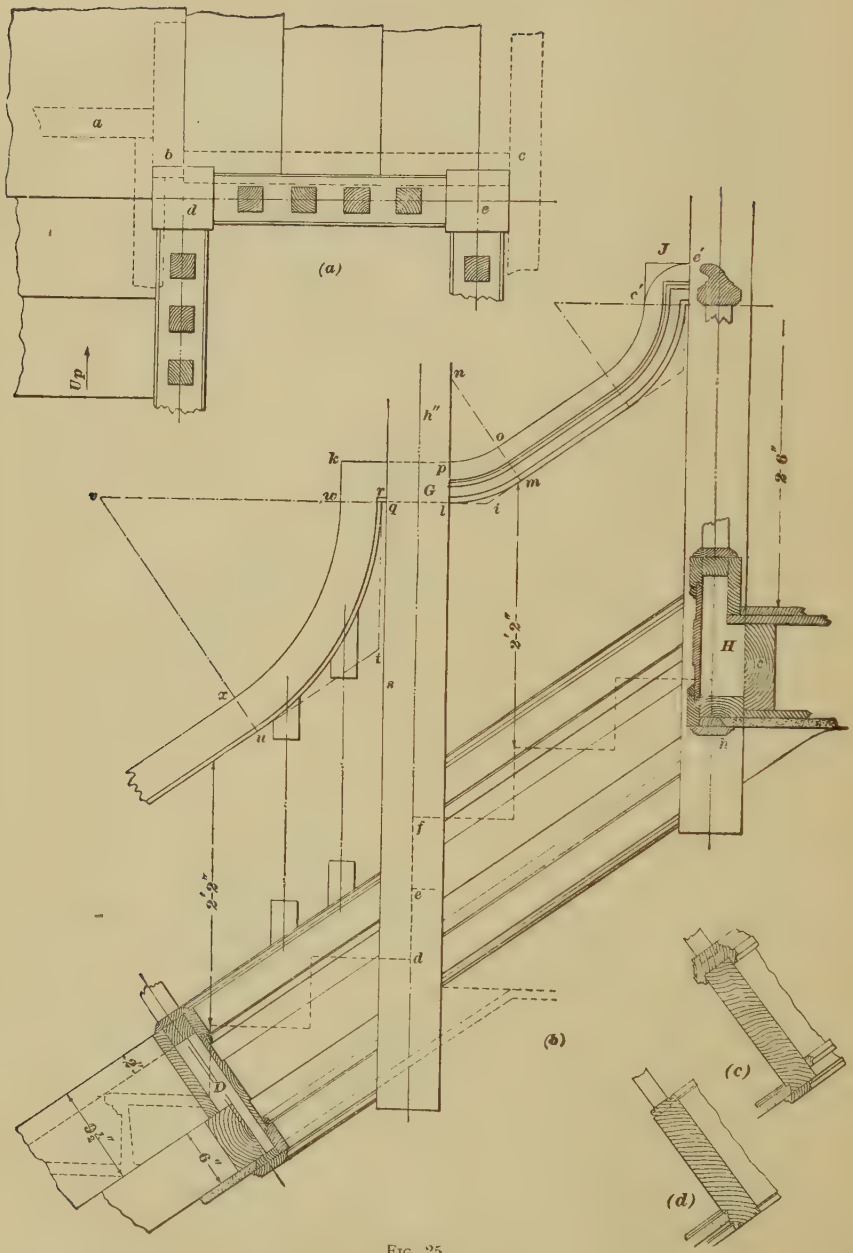


FIG. 25

the elevation, the first step is to set out the treads and risers as shown by the dotted lines. The balusters may be placed at any distance apart that is desirable on close strings, as their relation to the treads is not noticed. On the plan is shown the relation of the balusters with reference to the newels, from which measurements should be taken. Observe, in the elevation of the lower newel, that there are two risers at right angles to each other at the centre of the newel, one riser extending from the top step of the lower flight to the landing, and the other from the landing to the first step of the short flight, as shown at *d e f*. In this figure, the portion *d h e′ h″* is the elevation, or side view, of the short flight from *d* to *e* on the plan (*a*). A cross-section of the close string, illustrating the panel, timbers, blocking, etc., is shown at *D*, and from this the connections with the newels are drawn in as indicated. The section *H* along the floor level is the same as at *D*, but should it prove to be too high above the floor at any time, the panels may be reduced in width. Panel work of this character may have stiles at newel connections, and muntins at suitable intervals in the long flights and landing fasciæ. A more usual method of forming a close string is shown in Fig. 25 (*c*). In this case the outer string is solid and about 3 inches thick, and on top of this is fixed a solid moulded-and-rabbeted capping to receive the ends of the balusters. A flat moulding is planted on to the under side of string to cover the joint of the plaster soffit. The simplest and cheapest method of forming a close string is shown in Fig. 25 (*d*). In this case, three of the angles are beaded, and the balusters are fixed direct into the top of string. A small groove is formed in the lower edge of the back of string to take the edge of the plaster soffit.

31. Half-Newels. — In newelled staircases the rails should always finish against a half-newel at the wall connection, and the lower ends of the half-newels may be shown below the soffit. Where half-newels are placed on the walls opposite the landing newels, ornamental flat-arch spandrels may be framed between each newel and half-newel, thus finishing the soffit of the landing.

32. Newel Posts and Rails.—The length of newel posts is governed by the depth of the string, including the soffit moulding.

Fixing the height of the easement at *G*. Fig. 25 (*b*), and the

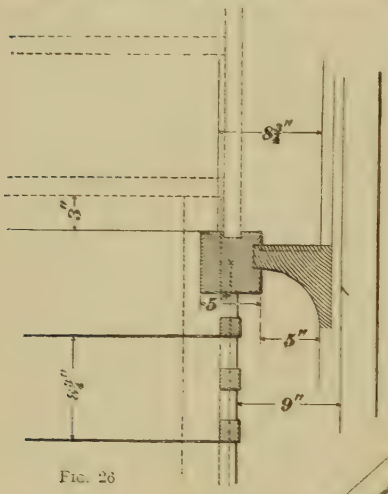


Fig. 26

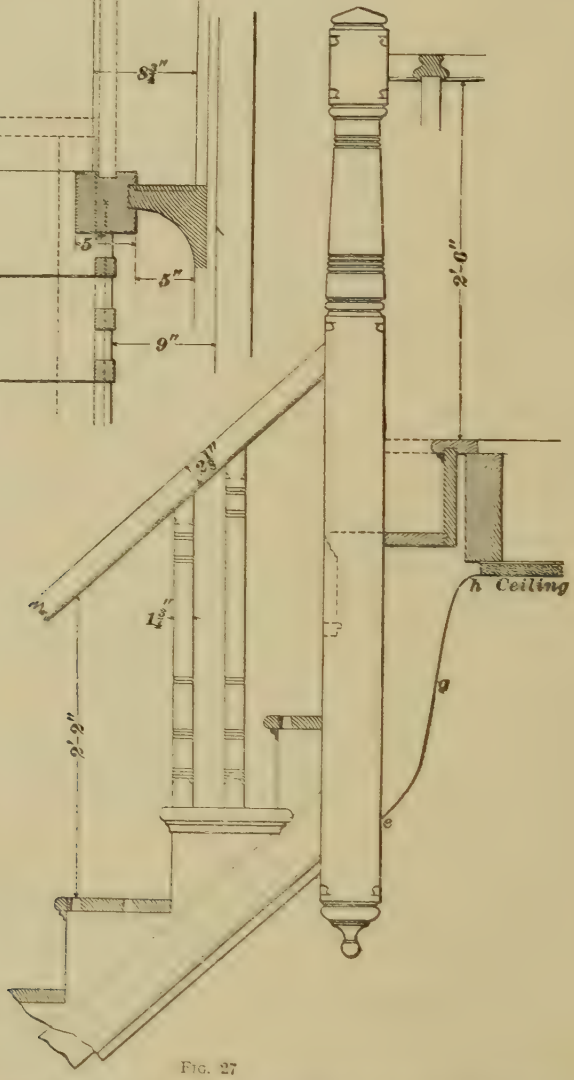


Fig. 27

height of the level hand rail at *f*, the height of the hand rail up

the flight is set out, and the rail is made parallel with the line of the string. There is nothing important in the position of G, except that it fixes the level of the knee at k. To produce a good easement, draw the horizontal line $l\,i$ at the required height of the easement and continue the bottom line of the inclined rail until it intersects this horizontal line. Set off $i\,m$ equal to $i\,l$, and draw $m\,n$ at right angles to $i\,m$. Let $m\,o$ equal the thickness of the hand rail; from n as a centre, describe the easement lines $o\,p$ and $m\,l$. For the ramp and knee, make $q\,r$ from $\frac{1}{2}$ to $1\frac{1}{2}$ inches; at right angles to $q\,s$ draw $r\,v$, which is a continuation of $i\,l$. Draw $r\,t$ parallel with the newel, and continue the bottom line of the rail until it intersects $r\,t$; make $t\,u$ equal to $r\,t$; from u draw $u\,v$ at right angles to $t\,u$; make $r\,w$ equal to the thickness of the rail; and draw $w\,k$ parallel to $q\,s$. With v, the intersection of $r\,v$ and $u\,v$, as a centre, describe the arcs $r\,u$ and $w\,x$. The ramp and knee at the upper landing are defined in the same way. The rail may be curved as indicated by the arc $c'\,e'$, forming a goose neck.

33. Special Arrangement of Newels.—In Figs. 26 and 27 are shown a plan and an elevation, respectively, of a quarter-landing staircase having a quarter-turn wreathed string connection to the landing, thus avoiding the use of a second newel.

34. Newel Between Wreathed Strings.—Fig. 28 shows a plan of a staircase with a newel post set between quarter-turn wreathed

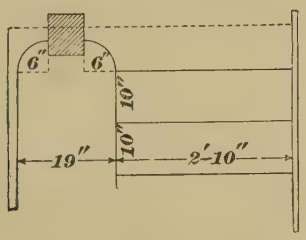


Fig. 28

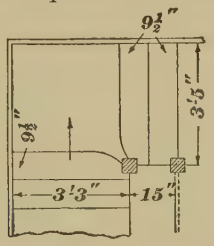


Fig. 29

strings on the landing of a flight. The hand rail in this case will be bolted to the newel.

35. Quarter-Landing With Newels.—Fig. 29 shows a plan of a quarter-landing staircase with small newels framed to the

string in the angles; the hand rail may join the newels either straight, with easements and with ramp and knee, or with a goose neck. The curved risers are introduced to save space in the run of the flights.

36. Landing Staircase With Two Return Flights.—In Fig. 30 is shown a plan of a landing staircase with two return, or *wing*,

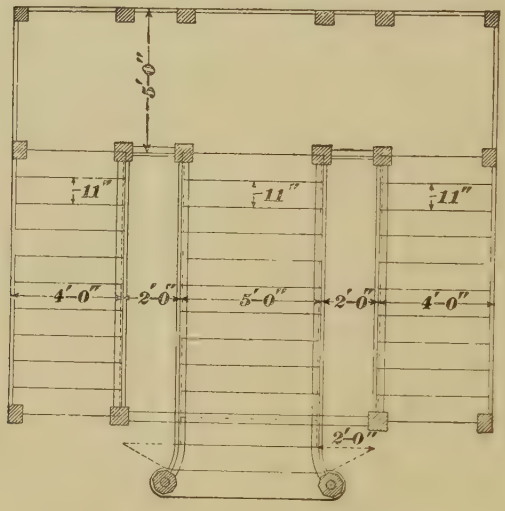


FIG. 30

flights, suitable for a public building. The flights and landing may be wainscoted, and, by the introduction of half-newels set against the wall opposite the regular newels, a good structural effect is obtained. The regular and wall newels may be carried up as columns and pilasters, further improving the treatment. Flat, ornamental arches may be introduced between the newels and half-newels, where they extend below the soffit of the landing, to break up and panel the soffit spaces. For a public staircase of this character, in wood, a better effect is produced by omitting the plaster to the soffit and showing the framework, in which case all the construction timbers should be finished wrought, or with a smooth surface, and not left rough.

37. In Fig. 31 are shown a plan (*a*), an elevation (*b*), and a development (*c*) of a straight staircase, with a single newel set

diagonally at the landing, the string fascia and hand rail being curved to enter two adjacent faces of the newel. In the plan, *a b d c* is the position of the carriage timber, and *A* and *B* indicate the position of the floor joists. Half-balusters are set against the sides of the newel, to which the hand rails are connected. In the elevation, *a'*, *b'*, *d'*, *c'* show the depth and position of the carriage timbers, and *A* is the landing floor joist. In the development (*c*), set off from the face of the riser *s' e'* equal to the corresponding distance on the plan, designated at *o s*, which is the

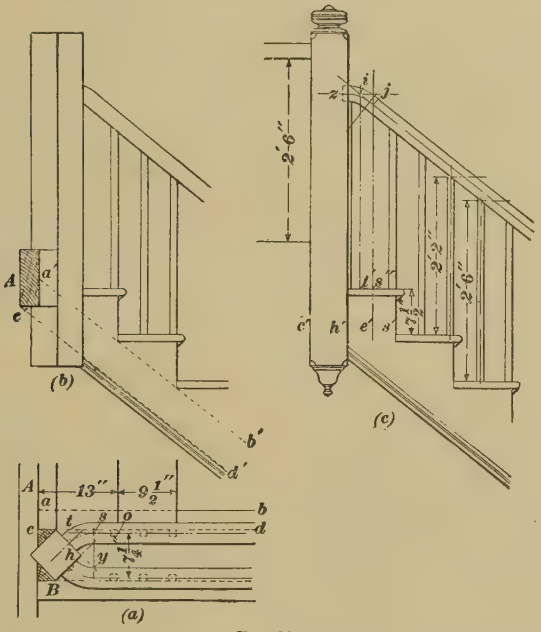


Fig. 31

distance from the face of the riser to the face of the curve; then, set off *e' h'* equal to the arc *s h* on the plan. Through *h'* and *c'* erect perpendiculars for the sides of the newel. Through *e'*, draw *e' j* parallel with the face of the newel. Set off *s'' t'* equal to *s t* on the plan; parallel with *s'' j*, draw *t' i*. From the point where this line intersects the centre line of the inclined rail, draw *i z* parallel with the tread, then *j i z* is the centre line of the hand rail. This fixes the height of the hand rail at the newel; the

level rail is 2 feet 6 inches above the floor. The easement curve at the top of the rail is entirely independent of the horizontal curve on the plan, and may be determined by setting off equal tangents on each side of i and erecting perpendiculars to the respective tangents. The point of intersection of these perpendiculars is the centre for the easement curve $z\,j$. The horizontal curve in the plan is determined by setting off $t\,s$ equal to $t\,h$ and drawing perpendiculars $s\,y$ and $h\,y$. Then, y is the centre for the curves of the rail and string.

38. Swelled Steps and Curved Strings.—For a pleasing effect, the start of a staircase is often widened by curving the front string and increasing the width of several treads by curving the risers. Fig. 32 shows the plan of such a staircase and the development of the string and hand rail. To find the height at which the hand rail enters the newel, draw the bottom line of the rail through the points where the centres of the short balusters would occur, as at $d\,d'$; set off from $d\,d'$ the thickness of the hand rail, 2 inches, and draw the centre line of the hand rail $e\,f$. The tangents $c\,k$ and $c\,a$ are equal, and k is the point where the hand rail joins the newel. Make $g\,f$ equal to $m\,k$, draw $c\,o$ vertically, and through o, the point where $c\,o$ and $e\,f$ intersect, draw $h\,j$ at right angles to $c\,o$. If the hand rail is brought to a level

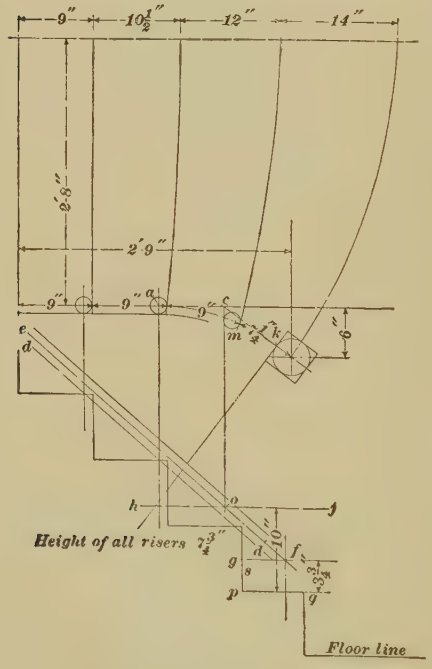


Fig. 32

on $o\,j$, its height will be 10 inches above the bottom step $p\,q$. In this development, the hand rail is below its real position a distance equal to the height of a short baluster, or 2 feet 2 inches. This distance added to 10 inches gives 3 feet as the distance from the first step $p\,q$ to the centre of the hand rail at $h\,j$. If the hand rail is without an easement to the newel, as at f, its height will be 2 feet $5\frac{3}{4}$ inches.

39. In Fig. 33 is shown a staircase starting at the newel with a curved string and swelled steps. The newel in this arrangement is to stand on the first step, the riser extending round to the string,

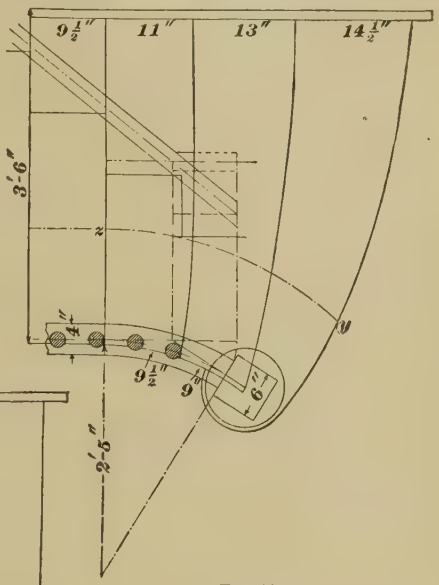


Fig. 33

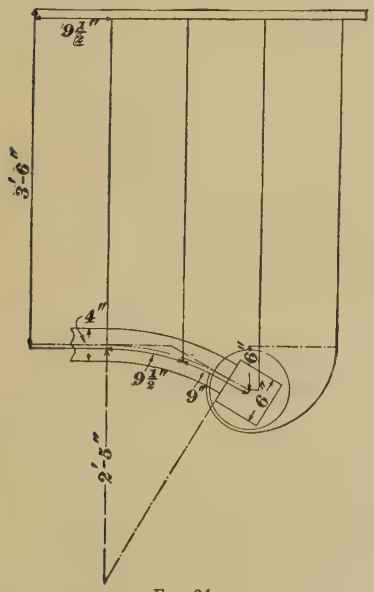


Fig. 34

which will receive it. Thus, the newel does not project beyond the line of the first step, and, where the space is limited, this method will help to overcome the difficulty. The height of the newel in this case may be determined by the method explained for Fig. 32. In Fig. 34 is shown a plan wherein the string is curved, but, with the exception of the starting one, the risers are made straight.

40. Curtail Step.—In Fig. 35 is shown a method of describing the curves of a curtail step. Draw a larger circle *a b c d* than is necessary to enclose the required scroll. Divide this into sixteen equal parts, and let the diameter of the eye of the scroll be equal to *e f*, in this case 7 inches. The diameter of the eye should always be somewhat greater than the width of the hand rail, which in this case is 6 inches. At right angles to *b d* and tangent to the eye, draw *e' i*; from *i*, draw *i j* perpendicular to *h g*; and so proceed, drawing lines at right angles to the successive radial lines, until *m*, the desired point, is reached. From the points of intersection *m*, *n*, etc., on the radial lines, with a radius equal to 3 inches, or one-half the width of the rail, describe circles as shown until one is tangent to the eye, as at *x*. From here each successive circle is smaller, so as to be tangent to the eye. Tangent to these circles, draw in an outline of the curve of the hand rail.

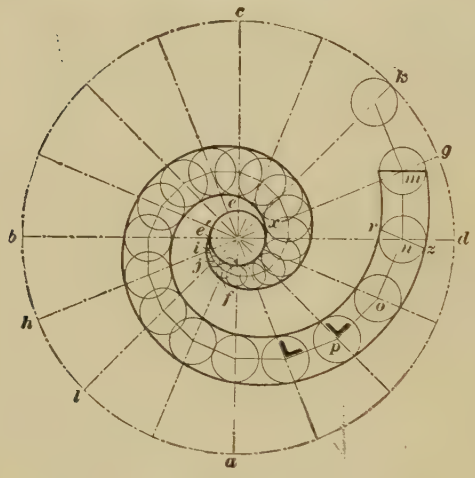


FIG. 35

41. In Fig. 36 (*a*) is shown a plan of the curtail step with curved steps receding from the same. This plan may be drawn from the dimensions given, taking as much of the scroll delineated in Fig. 35 as is required to fulfil the conditions. At *z r*, Fig. 36 (*a*), is shown the junction of the scroll with the straight hand rail. Where the scroll has been developed in a diagram, as shown in Fig. 35, the whole or any part of it may be transferred to the plan of the staircase, as was done in Fig. 36.

42. In order to fix the height of the wreathed portion of the scroll, draw an elevation of the risers and treads as in Fig. 36 (*b*).

Draw the bottom line of the hand rail $x\,x$ through the points on the treads where the centre lines of the short balusters intersect; then draw the centre line $c\,b$ of the hand rail, and make $f\,s$ equal to $j\,a$ in (*a*). Parallel with the riser lines, draw $c\,a$ through s, and make $t\,i$ equal to, say, 2 inches, thereby fixing the height of the eye and the level portion of the scroll. Make

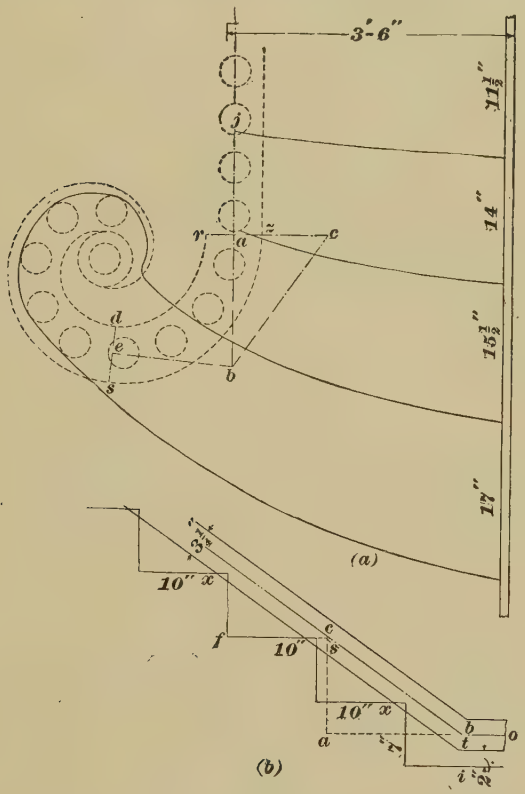


FIG. 36

$t\,b$ equal to one-half the depth of the hand rail, and draw $b\,a$ parallel with the tread line. Then, as the bottom line of the scrolled rail is 2 inches above the first step i, and the length of a short baluster is 2 feet 2 inches, the height from i to t will be 2 feet 4 inches when the hand rail is in position. The scrolled

hand rail should be kept as low as that shown, so that its varying and pleasing curvature will be seen to the best advantage.

In the plan, Fig. 36 (*a*), *a b* is the centre line of the hand rail prolonged, and *a c b* is taken from lines similarly lettered in (*b*). From *b*, draw *b e* tangent to the centre line of the hand rail at *e*. The joint *s d* is made at right angles to *e b*. From *s d* to *z r* is the wreathed portion of the hand rail, since it both curves and rises. The remaining portion of the scroll, from *s d* to the eye, is horizontal, as shown by *b o* in the elevation (*b*); and in this part of the scroll three or four of the balusters should be bolted at their bases to the step and at their tops to the scrolled rail. The construction of the veneered riser and scroll block is shown in Fig. 37 (*a*), and the complete scroll step is shown in (*b*).

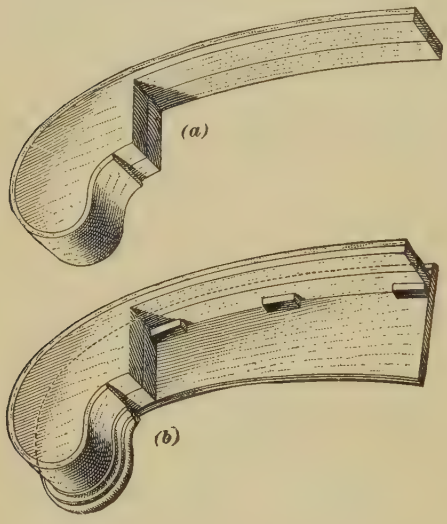


Fig. 37

43. Geometrical Staircases.—In a geometrical staircase, the hand rail sometimes travels over six or more flights from the first step to the last; it then becomes necessary to wreath or curve the string and hand rail round the well hole. The construction of a geometrical staircase is similar in all respects to that for one having straight flights, with the exception that the outer strings must be curved round the well hole. The strings are framed in between the trimming joists at the floor levels, and are further supported by what are called *pitching pieces*, or bearers let into the walls, carefully fixed and wedged up and projecting under the treads to the outer string.

In Fig. 38 are shown a plan (*b*) and elevation (*a*) of a geomet-

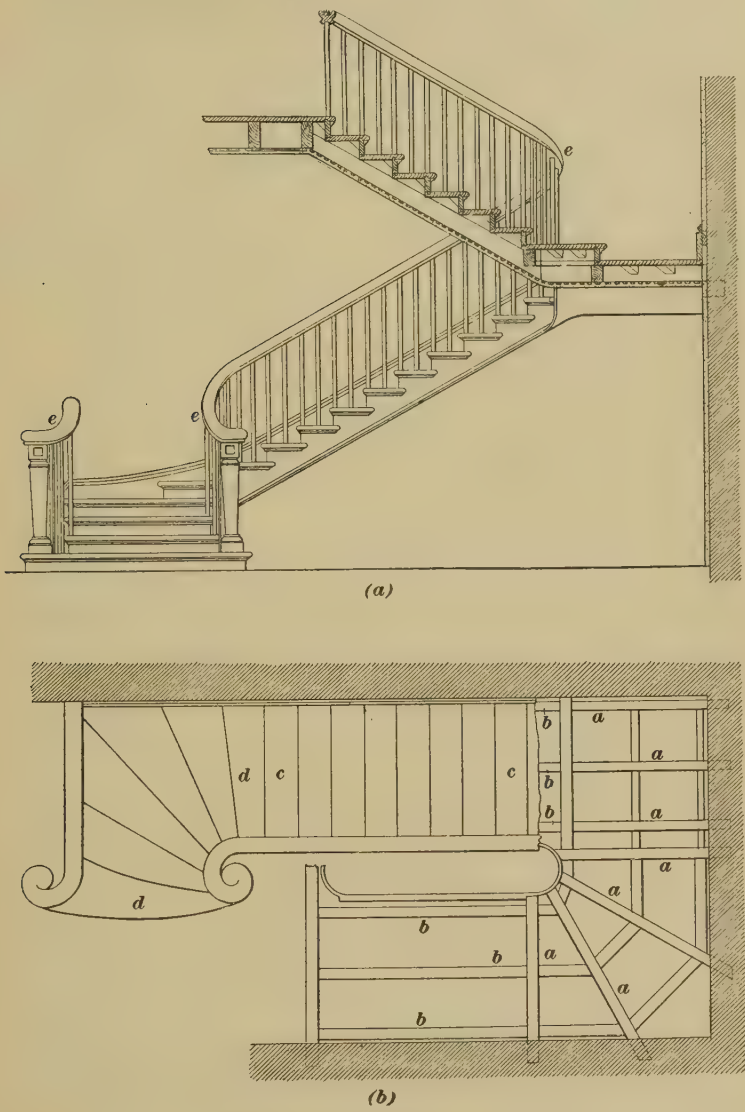


Fig. 38

rical staircase, where the pitching pieces are shown at *a*, the

carriages at *b*, the steps at *c*, and winders at *d*, while the hand rail is shown at *e* wreathed round the open well hole.

44. Method of Forming Wreaths.—Before studying the various forms of geometrical staircases, it is necessary to understand the method of forming the wreathed scrolls of the outer string. On a piece of straight string, long enough to contain the wreath, allowing about 12 inches at each end for joints, set out the intersections of the treads and risers and the points between which the string is to be curved. From the portion *a*, Fig. 39, between the points at which it is to be curved, remove enough wood to permit the string to be bent round a special block, called the **cylinder**, which is cut to the exact size of the curve of the finished face of wreath. The string is held in position by clamps *b*, and the back of the veneer is filled in with small fillets *c* glued in position and firmly held together with canvas and glue. The ends of the wreath are then cut off where required and jointed to the straight strings with grooves and tongues and stiffened with wood fillets on the back tightened up by means of wedges.

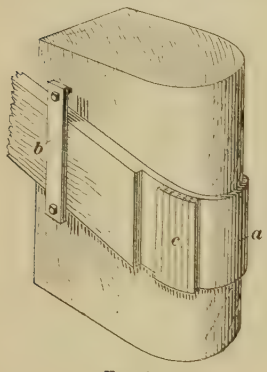


FIG. 39

GEOMETRICAL STAIRCASES

45. Straight Staircases.—In Fig. 40 are shown the plan (*b*) and section (*a*) of a **straight staircase** with a wreath 6 inches in diameter. In planning this staircase the first requirement is to fix the height and number of risers. The story rod shows that the height of the story is 9 feet 4 inches, or 112 inches. As the space available is limited, 8 inches is taken as the height of each riser, so that the height of the story, or 112 inches, divided by the height of the individual riser, or 8 inches, gives 14 as the number of risers in the flight. The total run *c d* is 10 feet 1 inch, less 4 inches for the depth of the wreath, which leaves 9 feet 9 inches to be divided into thirteen treads, giving 9 inches as the width of each tread.

As the floor at the landing makes one of the steps, there is one tread less than the number of risers. The width of the staircase, shown in (*b*) as 2 feet 9 inches, is measured from the face of the plaster to the face of the outside string; while the width of the well includes the width of the stairs, the diameter of the wreath,

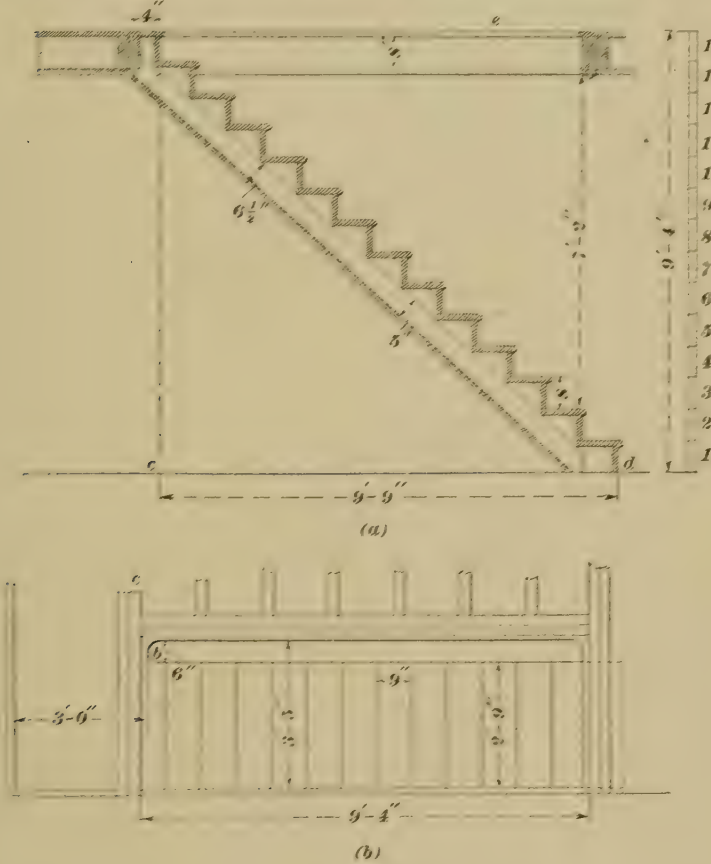


FIG. 40

in this case 6 inches, plus 1 inch for the thickness of the fascia and 1 inch for lath and plaster, altogether 3 feet 5 inches; and, if the outside wall is constructed of brick, 1 inch more for thickness of furring or strapping, when used, will be required. At the

landing of a straight flight there must be at least as much room between the wreath and the partition as the width of the staircase, preferably as much more as possible. In this case, 3 feet is the width used in the landing, the 3 inches extra being allowed for convenience in moving furniture, etc.

The headroom of the staircase shown in Fig. 40 is 7 feet 2 inches from the top of the second step to the ceiling, and the point where this headroom can be secured governs the length of the well hole, which, as figured on the plan, is 9 feet 4 inches. It is not necessary to make a drawing of the elevation in order to find the length of the well hole for the required headroom, as this can be calculated from the plan by counting twelve risers down. If each riser is 8 inches, the twelve risers make 96 inches. From 96 inches subtract 10 inches, the depth of the floor, giving 7 feet 2 inches as the headroom. The twelve treads of 9 inches each make 9 feet, to which must be added 3 inches for the depth of the wreath and 1 inch for its thickness, making the total length of well hole 9 feet 4 inches. The hand rail for such a staircase as this would be from 3 to $3\frac{1}{2}$ inches wide, and moulded, and the balusters from $1\frac{1}{2}$ to 2 inches, square or turned.

46. Landing Staircases.—In Fig. 41 is shown the plan (*a*) and the section (*b*) of a **half-turn landing staircase,** with a continuous hand rail round a 7-inch wreath. A staircase of this kind is easy to ascend, as the flight is broken by a roomy landing. This arrangement also provides space for a window to light the staircase and hall from above the landing, while below it affords room for a doorway to the outside. With the latter purpose in view, the soffit of the landing must not be less than 7 feet in height. The plan also indicates the timber framing of the well and the landing. A spandrel panel is shown at the start of the staircase in the elevation (*b*), the object of which is to close and neatly finish the angular space formed by the intersection of the string and the floor. The height of the spandrel panel is such as to receive the hand rail of the basement staircase. Where it is desired, the latter staircase may be enclosed by a panelled or lath-and-plaster partition extending up to the string of the upper flight.

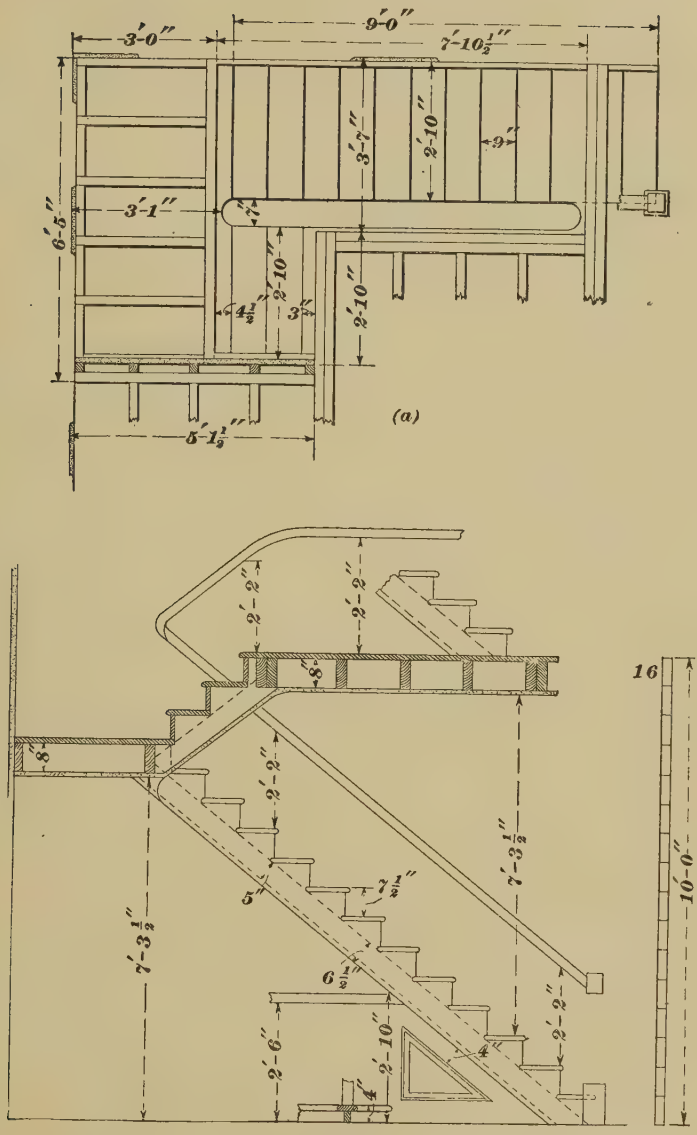

3′-0″
9′-0″
7′-10½″
3′-7″
2′-10″
9″
6′-5″
3′-1″
7″
2′-10″
4½″
3″
2′-10″
5′-1½″
(a)
2′-2″
2′-2″
8″
16
8″
2′-2″
7′-3½″
5″
7½″
7′-3½″
6½″
10′-0″
2′-6″
2′-10″
4″
2′-2″
4″
(b)

FIG. 41

The hand rail on the flight is 2 feet 2 inches in height from the centre of the short baluster at the top of the step to the bottom of the rail. Along the hall, the bottom of the rail is 2 feet 6 inches from the floor. These heights are based on the commercial custom of turning ordinary pin balusters in lengths of 2 feet 4 inches and 2 feet 8 inches, 1 inch being allowed for entering the hand rail and 1 inch for the dovetail entering the tread, thus leaving the exposed part the lengths mentioned.

47. The half-turn landing staircase can be altered in various ways without changing the number of risers. For instance, a step can be taken from the upper flight and added to the lower flight, increasing the run 9 inches and raising the landing one riser, making it 7 feet 11 inches. Then the well hole for the same headroom must be 9 inches longer, and the beam at the landing of the short flight must be brought forward the same distance. On the other hand, a step may be added to the short flight, making four risers in the short and leaving twelve risers in the long flight. The well hole may then be shortened 9 inches and still have the same headroom as before, but it will be necessary to move the landing beam of the short flight back 9 inches to accommodate the additional step. The landing, however, is one riser lower, making it 6 feet 8 inches, but, if the total depth of the landing can be made 6 inches, thus reducing its depth 4 inches, the height of the soffit of the landing will be 7 feet.

48. Winding Treads.—In Fig. 42 is shown an **enclosed staircase,** illustrating the method of setting out the wall string, easing curves, etc. The widths of the winding treads at the wall are projected down from the plan by lines *k l*, *m n*, etc. Then, the wall string *a b*, at right angles to the main wall string *a e*, is revolved, as shown, parallel with the main wall string, and set out in a similar manner ; *a' b' c' d'* shows the string *a b* in elevation. The string *e f* is treated in a similar manner. The story rod is shown at the left, and the steps are projected from it and from the plan, as shown at step *4*. Where the treads are wide, as in steps *1*, *2*, and *3*, the line of the nosings makes an angle with the horizontal different from that made by the line of the nosings in the body of the staircase. This is because the uprights, or

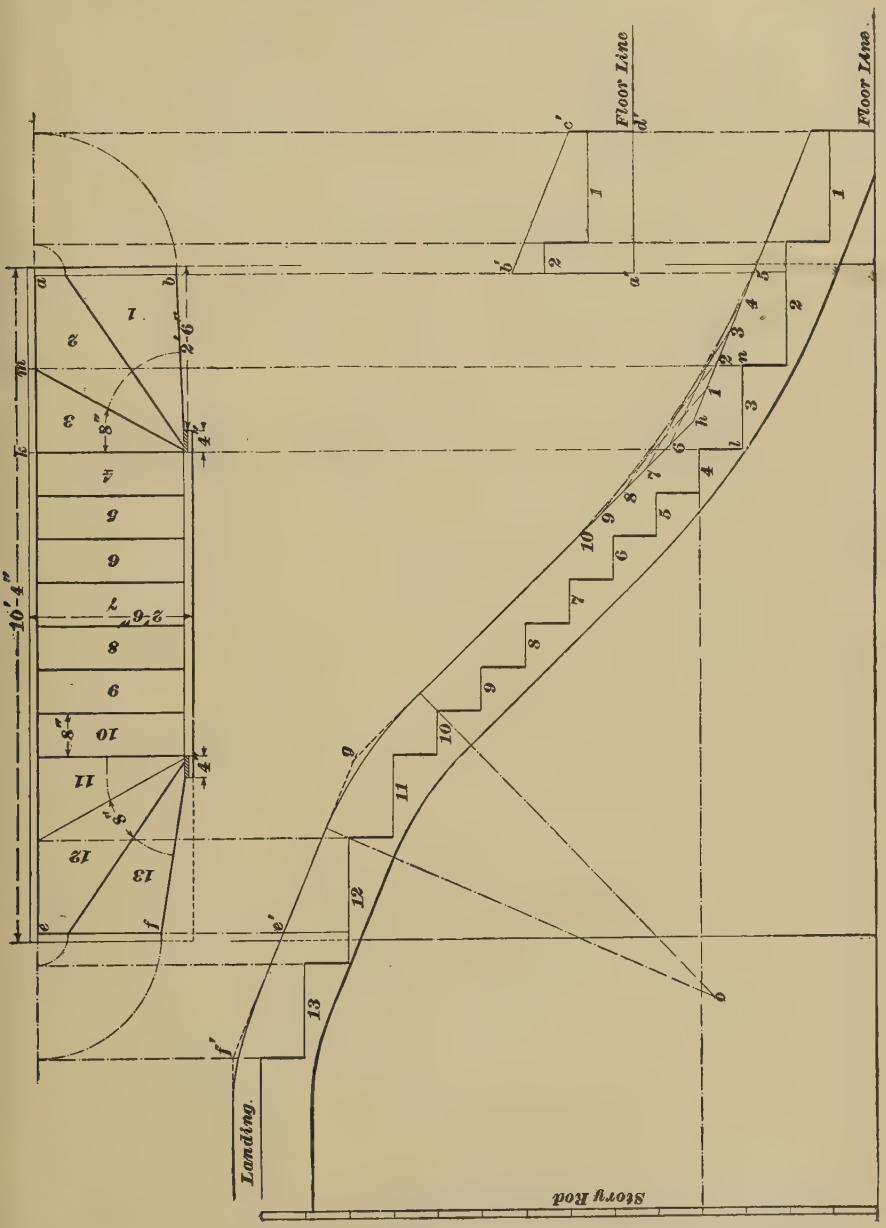


FIG. 42

risers, remain the same, while the horizontals, or treads, vary in width.

49. Easing Curves.—At the angles, easing curves are necessary or, at least, advisable. At *h*, Fig. 42, is shown a method of drawing an easing curve. From the vertex *h* set off equal distances in both directions, as *1*, *2*, *3*, *4*, etc. Draw lines from *5* to *6*, *4* to *7*, etc. Through the points of intersection of these lines, draw a curved line by means of a spline. If the angle is sharp, as at *g*, perpendiculars may be drawn at equal distances from *g* until they intersect, as at *o* ; the curve can then be drawn with compasses.

50. Items of Detail.—In winding treads, both wall and front strings should be mortised, or housed. For the steps, the treads and risers should be glued together, wedged, and back-nailed, in order to secure good solid work. The front string should have a vertical strip 4 inches wide spliced and glued to it, so as to receive the winders. The well must be framed wide enough to include, besides the figured width of the staircase, the thickness of the enclosing lining.

51. Double Winders.—In Fig. 43 is shown a staircase winding one-quarter turn at the top and the bottom, with an 8-inch wreath for a continuous hand rail. In planning winding staircases, it is important to make the treads as nearly as possible of the same width on the line of travel. This line should be about 14 inches from the face of the string, as shown on the plan (*a*). The width between finished walls for this staircase should be at least 6 feet 4 inches, as follows : Width of staircase from finished wall, 2 feet 10 inches ; diameter of wreath, 8 inches ; hall passage, 2 feet 10 inches. The distance from the finished wall to the wreath is made 3 feet 1 inch, so as to allow room for moving furniture. Where the staircase is continuous, the first and last risers of each flight should be placed 2 inches beyond the landing fascia line, in order to make a proper finish with the fascia.

In commencing the drawing, the starting and landing risers are marked on the plan, and the line of travel is divided equally.

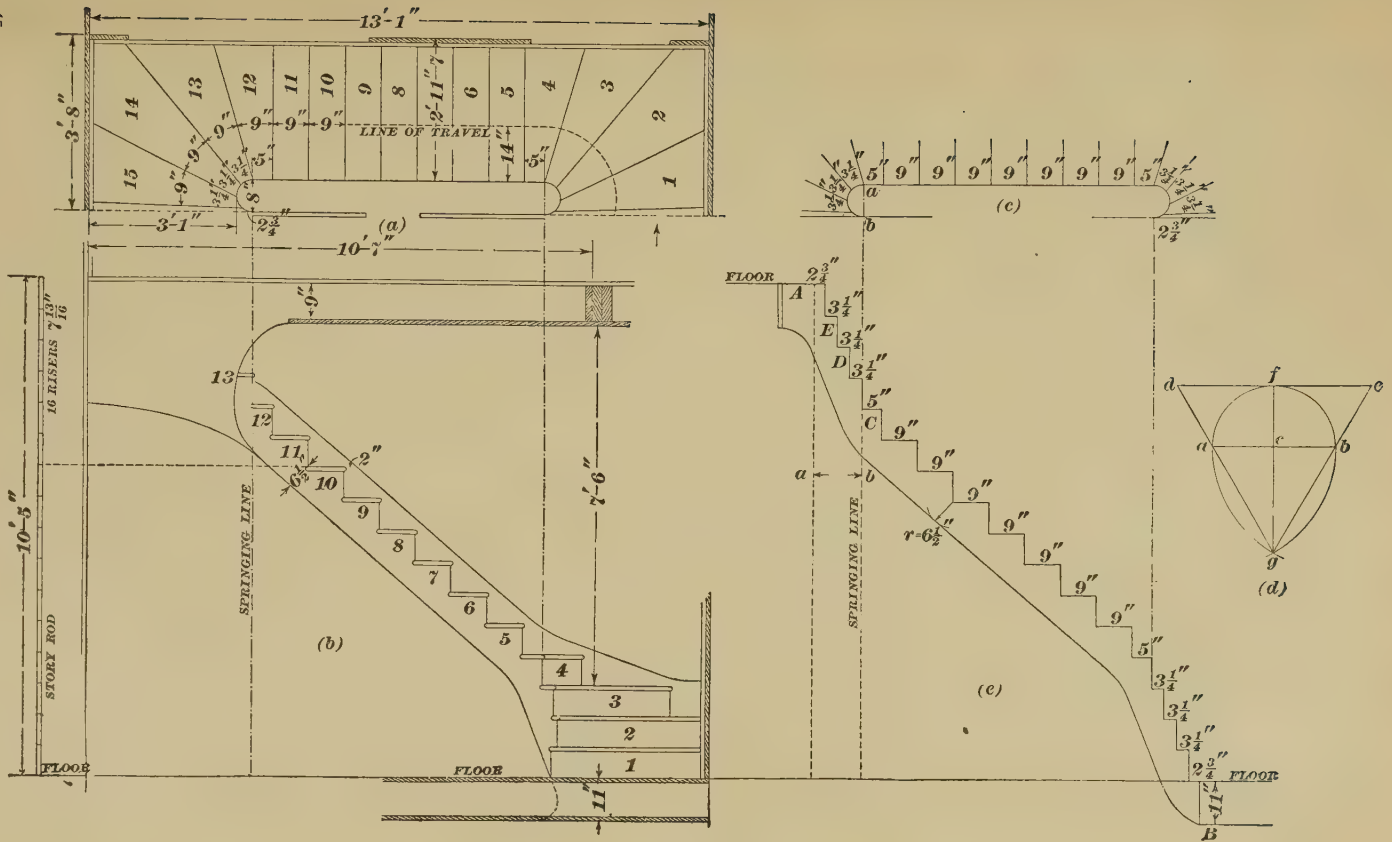

13'-1"
3'-8"
LINE OF TRAVEL
2'-11"
14"
3'-1"
2¾"
(a)
10'-7"
16 RISERS 7 13/16"
10'-5"
STORY ROD
SPRINGING LINE
7'-6"
FLOOR
(b)
(c)
(d)
(e)
r=6½"
A
B
C
D
E
a
b
c
d
e
f
g

FIG. 43

Then, the space along the wreath is divided, and, lastly, the risers along the straight string are drawn in position. Lines are drawn through the points found along the line of travel and passing through the points set out along the front string, thus completing the plan of the staircase. The elevation (*b*) of the staircase is drawn by projecting the lines of the risers down from the plan and by drawing the lines of the treads horizontally from the story rod, as shown at tread *10*. For the development of the wall string, the method given in Fig. 42 should be followed. The headroom, as shown in Fig. 43 (*b*), is 7 feet 6 inches from the top of the third step to the ceiling.

52. Width of Winders.—The winding treads must be made of uniform width round the wreath, so as to obtain a uniform curve in the rail. In Fig. 43 (*a*) there is a 5-inch width between the straight flight and the wreath, which provides for a better easing, or ramp, from the pitch of the straight rail into the steeper pitch of the wreath rail; besides, if the winders are all contained in the wreath, a sudden and abrupt change of inclination in the staircase will be made, thus causing one to stumble and fall.

53. Development of Strings.—In Fig. 43 (*c*) and (*e*) are shown the methods of developing the front string when each end curves round a wreath. The plan (*c*) of the front string is the same as in (*a*). The distance *a b* in (*e*) is equal to the "layout" of the semicircular wreath, found as in (*d*), where *d e* is the *outstretched*, or developed, length of the curve *a f b*. This length may be determined as follows: Make *a b* equal to the diameter of the cylinder. From *c*, with a radius equal to one-half of *a b*, describe an arc *a f b*; from *a* and *b* as centres, with a radius equal to *a b*, describe arcs intersecting in *g*. From *g*, through the points *a* and *b*, draw lines *g d* and *g e*; through *f* draw a line tangent to the arc and parallel with *a b*. The points where this line intersects with the lines drawn through *g* will define the length of *d e*, or the developed length of the arc *a f b*.

A C B in (*e*) is the front string, any outstretched step, as *C*, being obtained by projecting the line of the riser vertically from the plan, and the tread horizontally from the story rod.

As the steps D, E, etc., in the wreath have their width marked on the plan as $3\frac{1}{4}$ inches, that width is therefore transferred to the development. The string in this case is $6\frac{1}{2}$ inches, measured from the angle between the treads and the risers. This width is marked out with compasses from each angle, and a pleasing curve is drawn tangent to the arcs, as shown. When a wreath is of this diameter, or smaller, at the bottom of the flight, the curve of the hand rail presents a better appearance, and it is more convenient when the rail over the regular treads is continued on its pitch into the wreath without ramping the straight rail. In this case there would be an easing introduced between the straight rail and the wreath piece.

54. Arrangement of Winders.—In Fig. 44 are shown the plans of two different staircases brought together for comparison, each having one-quarter turn with an 8-inch wreath and a continuous hand rail. It will be seen that a landing is obtained by the arrangement shown in (*b*), thus making the flight much more desirable. In view (*a*) there are four winders, differing but little

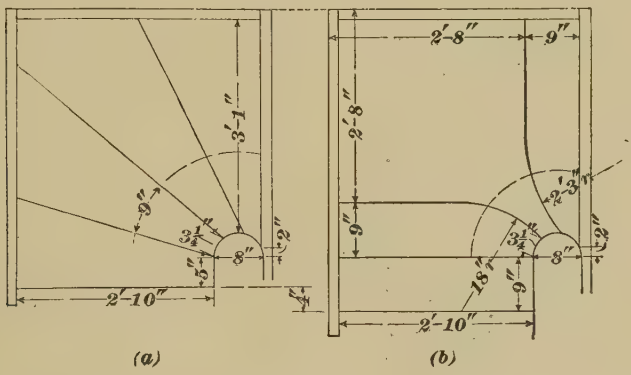


FIG. 44

from the plan shown in Fig. 43, while in (*b*) there are three winders with slightly curved ends. The five risers so changed in their arrangement in (*b*) take 4 inches more run than the plan with four winders, as shown. The placing of the carriage timbers in such staircases is a matter that requires care, as the strength and stability of the staircase depend largely thereon.

55. Carriage Timbers.—In Fig. 45 is shown the plan of the top winders of a staircase similar to that shown in Fig. 43, *a*, *b*, and *c* being the principal timbers in position. The timber *a* is set in place after the strings are put up, being nailed to the floor joist at *d* and fastened to the wall at *e*. A furring strip held in the direction *e d*, together with a straightedge tried along the line of the risers, will indicate the best position for this timber.

The bottom of the flight, as shown in Fig. 46 (*a*), may be timbered by securely placing a level piece *f k* extending from the front string into the wall, and then the two timbers *g h* and *l m*

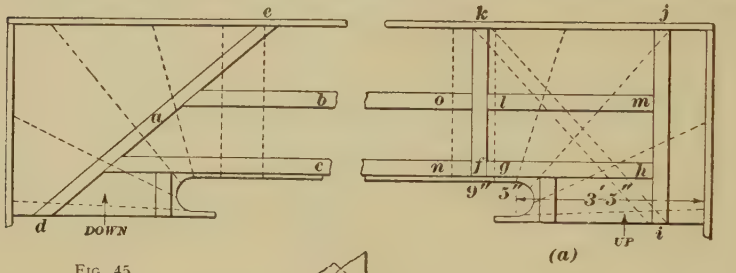


Fig. 45

at a steeper pitch than the main timbers *n* and *o*. To do this may require the insertion across the well hole of the floor joist *j i*; this is shown by the elevation in (*b*), where *l m* and *g h* of the plan are seen at *g′ h′*, and *n* and *o* at *n′*; or, omit the level piece *k f* and place a diagonal timber *i k* at the top, continuing the principal timbers *n* and *o* to meet it. The remaining timbers are filled in as required for furring, which must be done so as to allow the laths to be nailed on in the direction of the risers. In order to obtain a smooth curved surface on the soffit, which will be more or less winding, care must be taken to aline the blocking by means of a guide lath. In lathing so placed,

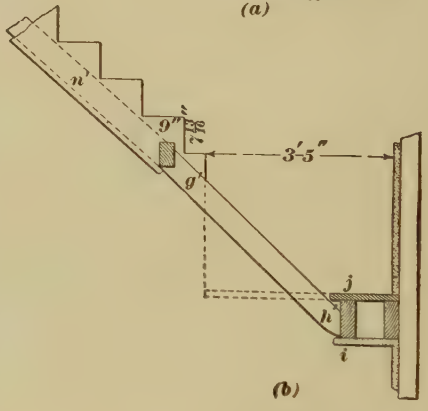


Fig. 46

care should be taken that space is allowed at all points for the key of the plaster, which, under staircases, is subjected at times to jarring that is likely to loosen it unless well keyed.

SPECIAL FORMS OF STAIRCASES

56. Quarter-Landing Staircase.—In Fig. 47 is shown a plan of a quarter-landing staircase, with a quarter-turn wreath for a continuous hand rail. Any radius of wreath considered desirable may be used, but if the risers *o b* and *o′ b′* are put at a distance equal to one-half the width of a tread from the point *a*, the intersection of the centre lines of the rail, the wreath piece will conform to the common pitch of the flights. If the front string is a close one, and the risers are placed as shown, the effect will be more agreeable than it would be if the risers were placed either nearer to or farther from the point *a*. This arrangement of the risers will allow a graceful curve in the development of the front string and the hand rail, while, if placed in any other position, the result will be an unsightly crippled rail and string.

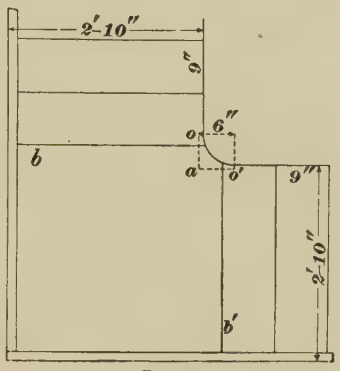


Fig. 47

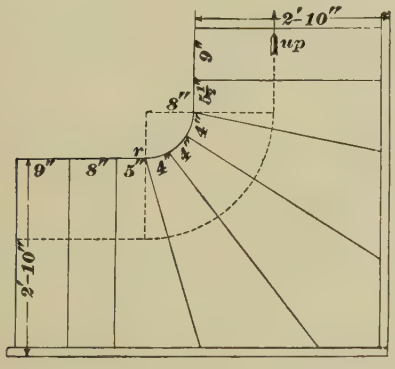


Fig. 48

57. Quarter-Turn Winding Staircase.—The plan of a quarter-turn winding staircase, with a quarter wreath for a continuous hand rail and with regular treads above and below, is shown in Fig. 48. The treads adjoining the wreath in both flights are reduced.

The benefit derived from the reduction will appear in the curve of the rail and the string, as it modifies the angle of intersection between the pitch of one straight rail and that over the winders, the string, of course, being affected in the same manner.

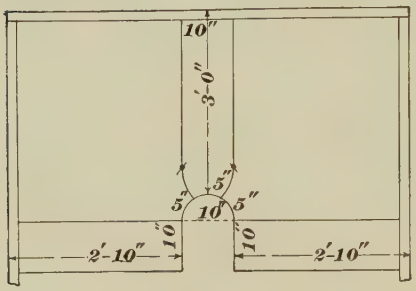


Fig. 49

58. Landing and Curved Risers.—In Fig. 49 is shown a plan of a staircase that includes two landings with a tread and two curved risers in the 10-inch wreath between the landings, making a half-turn. The wreathed rail over this plan has a pleasing shape, and no ramp is required in the straight rail either above or below the wreath.

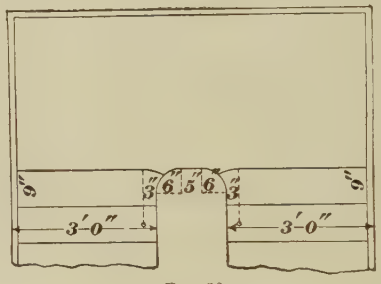


Fig. 50

59. Half-Turn Landing Staircase.—In Fig. 50 is shown a half-turn landing staircase. The face of the top riser of lower flight and that of the bottom riser of upper flight have a slight curve adjacent to the flattened wreath. By this method

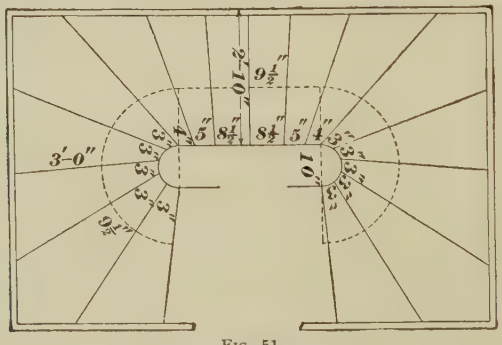


Fig. 51

the whole depth of the wreath is saved in the width of landing, which is an advantage where space is limited.

60. Winding Staircase.—Fig. 51 shows a plan of a winding staircase having seventeen risers. The wreaths for this continuous hand rail have a diameter of 10 inches. This arrangement is suitable where space is limited and where the entrance to the staircase is on the side.

61. Arrangement for Intermediate Floor.—Fig. 52 illustrates a plan for the starting and landing of two flights connected by a 12-inch wreath. Such an arrangement is used where the short flight ascends to an intermediate floor on the landing level.

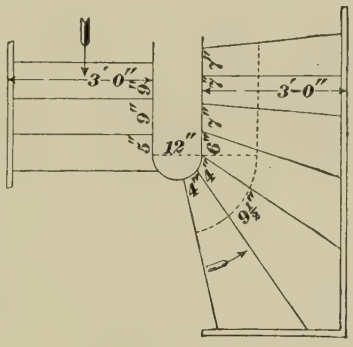


Fig. 52

62. Quarter Landing With Tangent Between Quarter Wreaths.—In Fig. 53 is shown a plan of a quarter landing staircase for a continuous hand rail. The wreath opening of 18 inches is formed by two quarter circles, each of 5 inches radius, with an 8-inch piece of

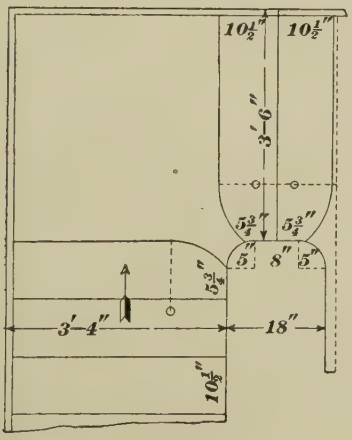


Fig. 53

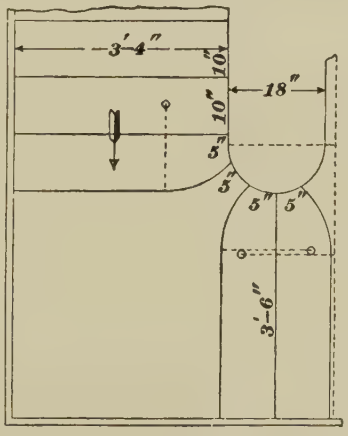


Fig. 54

straight string placed between. By this method a landing is secured, and angular winders are dispensed with; the length of the staircase is also reduced.

63. Quarter Landing With Semicircular Wreath.—Fig. 54 differs from the preceding plan only in the form of its wreath, which is semicircular in plan, and, while requiring a little more run, furnishes a more pleasing rail and wreath.

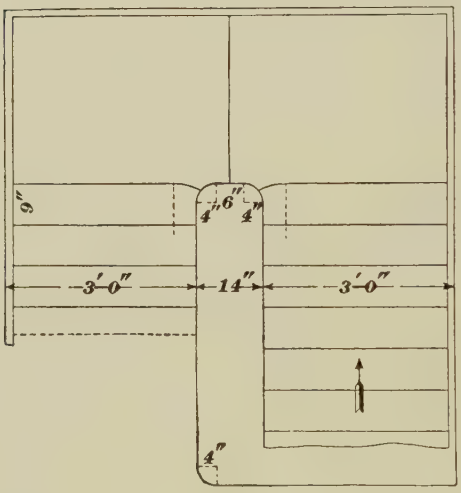


Fig. 55

64. Double Landings.—Fig. 55 shows a plan of a landing staircase making a half-turn, one riser at the centre of the wreath dividing the space into two landings. Where the run will permit, it is always advisable to dispense with this

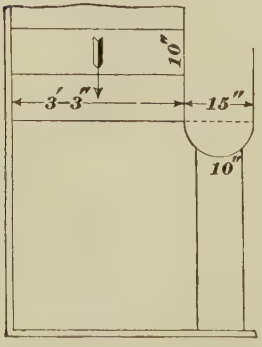


Fig. 56

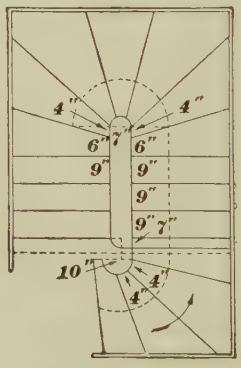


Fig. 57

central riser, thus adding breadth to the landing, and avoiding

the danger of stumbling at the step placed where it is not expected.

65. Quarter Landing With Step.—Fig. 56 shows a plan of a quarter landing staircase with a 15-inch wreath having a regular step at its centre.

66. Three-Quarter Turn.—Fig. 57 shows a plan of a winding staircase making a three-quarter turn, the entrance being at one end of the staircase.

67. Starting or Landing Winders.—Fig. 58 shows a plan of a staircase that has winders either at the starting or at the landing. The curving of the risers is resorted to for the purpose of making them occupy less room from *l* to *m*. Curving the risers in this manner also improves the appearance of the staircase by reducing its angularity.

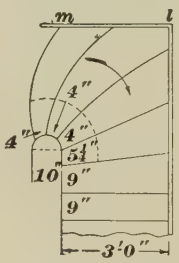


Fig. 58

68. Circular Staircase.—A plan of a circular staircase is shown in Fig. 59. All the risers except the three curved ones at the start radiate from the centre *b*, and are equally spaced at the front and wall strings. The front string along the first two steps is curved out, to increase the width of the staircase at the start, thus giving it a more pleasing appearance. A curtail step and a hand rail at the starting of such a staircase are very appropriate and attractive. The dotted lines indicate the position of the carriage timbers. A similar method may be followed for elliptic staircases.

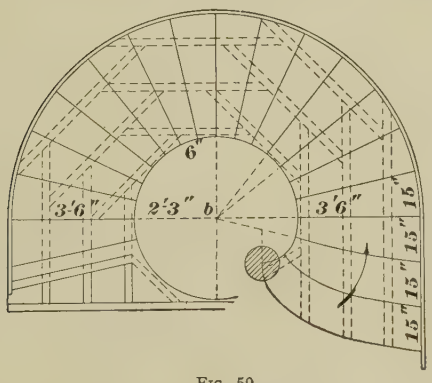


Fig. 59

Instead of a cylindrical front string, as in this plan, a circular newel post of sufficient length is sometimes used as a central

support, the treads and risers being framed into the central newel and into the wall string. The newel post may be cased with $\frac{7}{8}$-inch boards of the same width as the treads at the point of connection, thus affording support and enclosure-like mortises to the steps ; the grooves for the risers may also be cut out from the edge of the boards, thereby rigidly securing them. This casing, or staving, however, should not be set in place until all the steps are nailed in position.

69. Elliptic Staircase.—In Fig. 60 is shown a plan of an elliptic staircase. The customary method of providing a uniform width for the treads along the wall string, and also along the front string, causes some of the risers to stand at such an angle with the line of travel as to diminish the width of treads at those

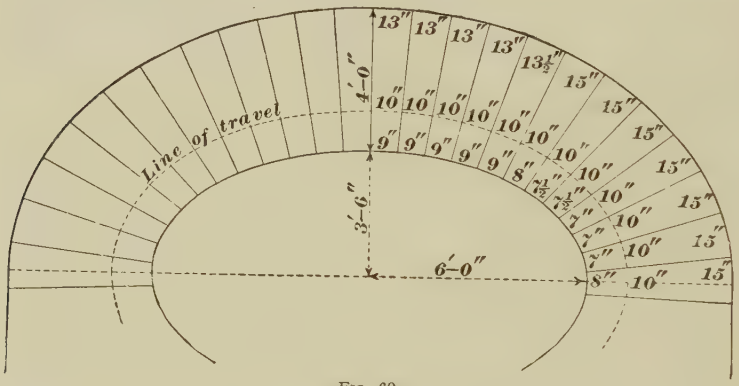


Fig. 60

points. It has the advantage, however, of giving the hand rail a uniform pitch from end to end. In another method, shown in the plan, the treads are divided equally on the line of travel, and the risers are drawn as nearly as possible normal to the front string.

PANELLING

70. The panelled wall lining for rooms and staircases is made of different heights, the arrangement and treatment of the panels being varied to meet the ideas of the designer. Dwarf panelling is known as a *dado ;* in Fig. 61 (*a*) is shown a dado as it passes from

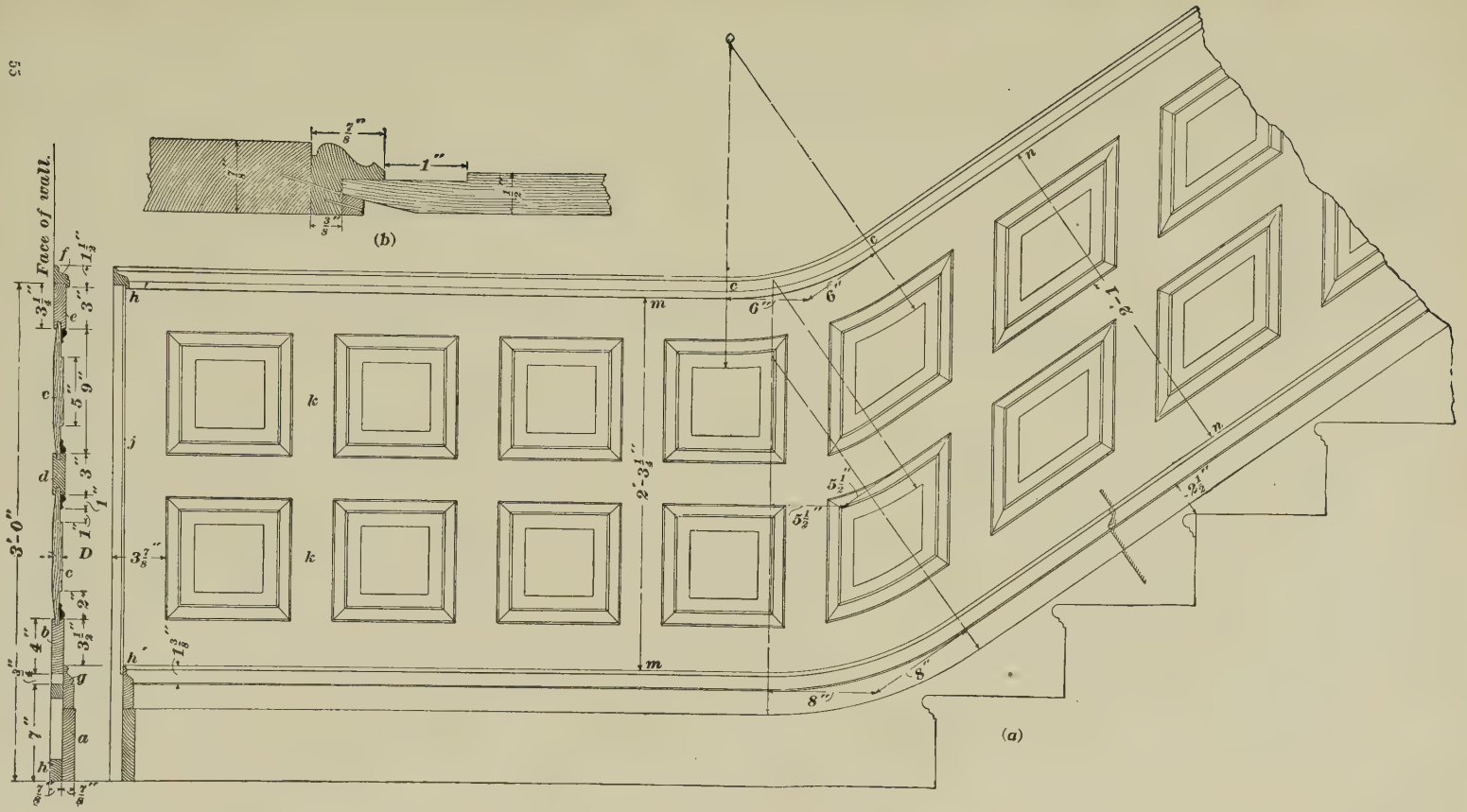

Face of wall.
3'-0"
(a)
(b)
2'-3¼"
1'-2"
6"
8"
5½"
2½"
3⅞"
1⅜"
1"
7/8"
3/8"
1/2"
3¼"
3"
5"
9"
1"
2"
4"
3½"
7"
a
b
c
d
e
f
g
h
j
k
m
n
D

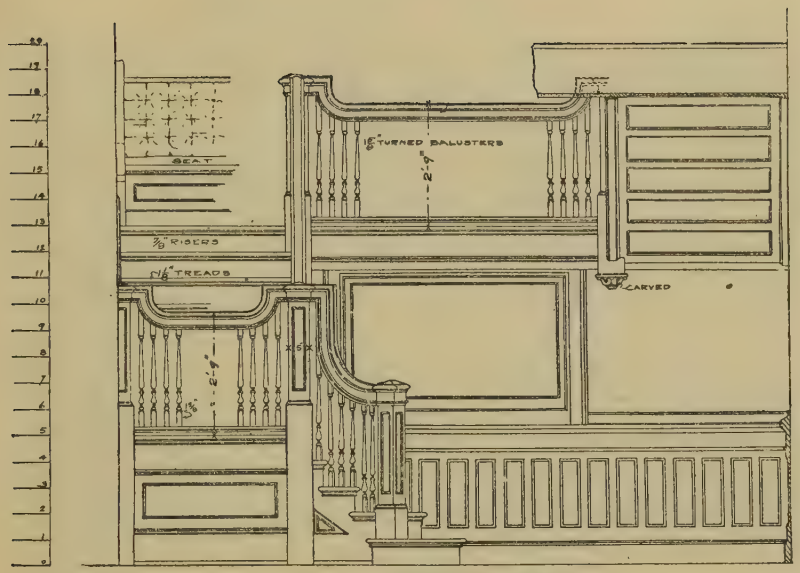
FIG. 61

the hall up the flight. A vertical section of the framework, panels, and mouldings as usually made is shown at *D*, where *a* is the lower member of the skirting; *b*, the bottom rail; *c*, *c*, the panels; *d*, the middle rail; *e*, the top rail; *f*, the capping mould; *g*, the base moulding or top member of the skirting; and *h*, the furring strip. In the elevation, *h' h'* is a stile with a groove *j* to receive the return wainscoting; at *k*, *k* are muntins. The stile *h' h'* extends the whole height, and the three rails are framed into it. The panels are square on the level portion, but up the flight they change their shape and become narrower, as the width of the wainscot *n n* is less than the width *m m*. The curves at the junction of the pitch and level lines are described from three centres, as shown; they cannot be described from a common centre, as the two portions are not of the same width. By producing the tangents of the level and inclined portions of the top, bottom, and central rails, and deciding on the length of the curves, radial lines may be drawn from the points, as at *c*, *c*, thus giving the centre, from which simple curves may be drawn.

In view (*b*) is shown a method of fastening the panels so that no nails will show on the face of the moulding. The panels are polished separately and put in place after the frame and mouldings are finished. The framework should be well seasoned, and the walls should be perfectly dry before the dado is set in position.

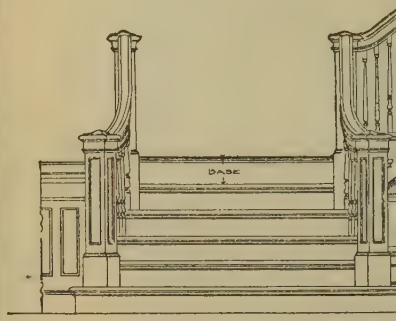
71. Completed Staircase.—In Fig. 62 are shown the complete working drawings of a staircase as an architect should prepare them for the builder, and in Fig. 63 is shown a view of the staircase when completed.

72. The balustrades of staircases are sometimes, especially in old work, treated in a very elaborate manner. In Fig. 64 is shown a view of one so treated, where the newels and balusters are elaborately carved.

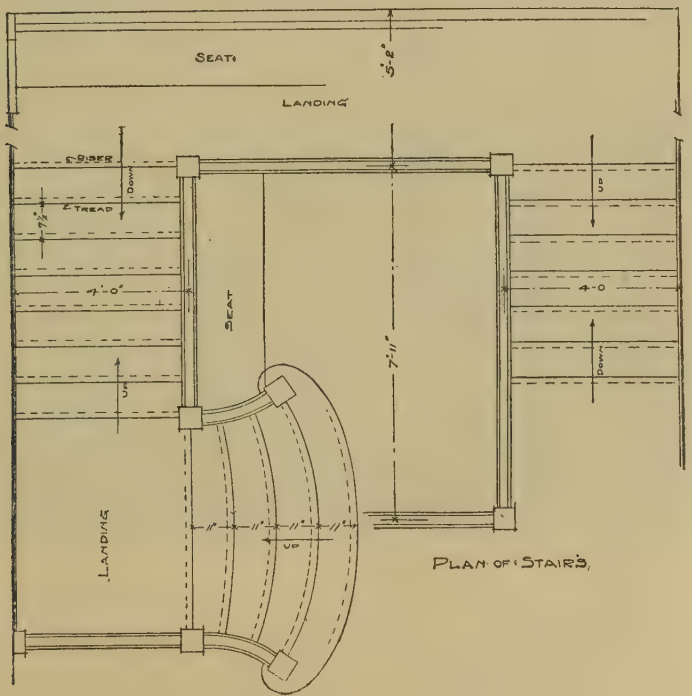


ELEVATION OF STAIRS.

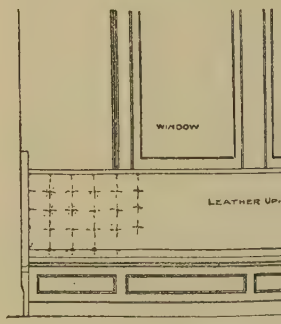
PANELLING UNDER STAIR LANDING



ELEVATION

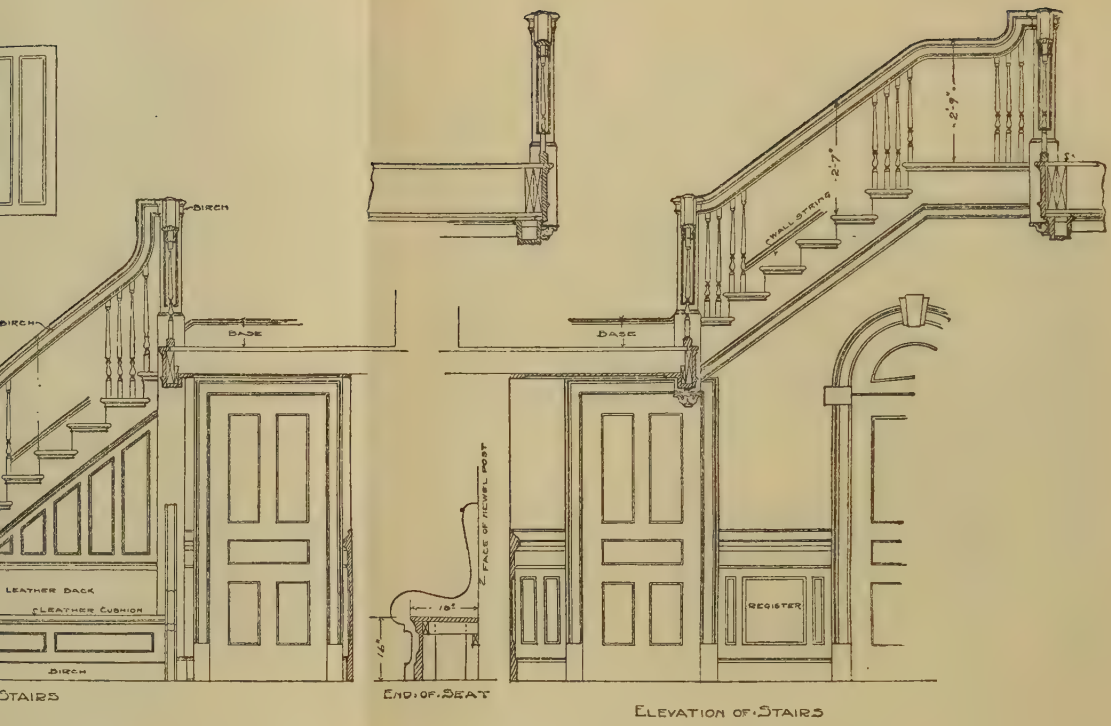


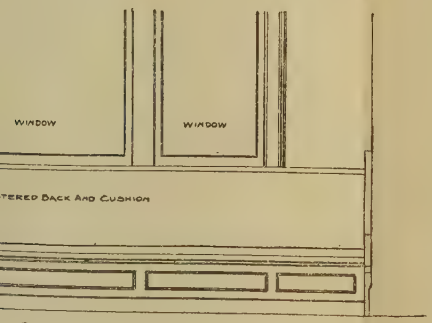
PLAN OF STAIRS.



ELEVATIO

FIG.


BIRCH
BASE
LEATHER BACK
LEATHER CUSHION
BIRCH
STAIRS
FACE OF NEWEL POST
18"
16"
END OF SEAT
WALL STRING
2'-7"
2'-9"
BASE
REGISTER
ELEVATION OF STAIRS


WINDOW
WINDOW
TERED BACK AND CUSHION
OF SEAT ON LANDING

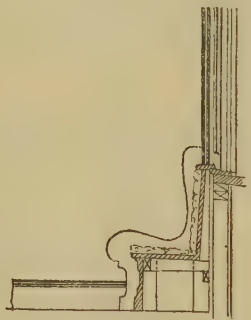

SECTION OF SEAT ON STAIR LANDING

Fig. 63

Fig. 64

IRONMONGERY

STAPLE IRONMONGERY

INTRODUCTION

1. The ironmongery used in building construction may be classified as *staple* and *finished*. **Staple ironmongery** may be considered as including such materials as nails and spikes, bolts and screws, sash weights, and other articles of this character, while **finished ironmongery** may include such devices and appliances as locks and latches, hinges, door and window fittings, and the various metallic fittings used in equipping the different classes of buildings. To this last classification the term *builders' ironmongery* is frequently applied.

While little consideration is given to the ironmongery on the average building, there is no more important part of the construction, nor one to which greater attention should be given. On the quality and the selection of proper ironmongery depends the avoidance of the petty annoyances often found in buildings where this subject has not received proper consideration.

The architect should be well informed regarding this subject, and should be in a position to know the kind and quality of ironmongery that, when specified, will give the best results. He will find that a thorough knowledge of builders' ironmongery will assist him materially in writing comprehensive specifications for this portion of the work. As far as possible, the ironmongery should be selected before the specification is written, so that a definite price for each article may be included in the builder's estimate. Variation in the choice of design may be made afterwards, but this will not necessarily vary the price.

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NAILS AND SPIKES

METHODS OF MANUFACTURE

2. The nails used by builders are of various forms and sizes and of various materials, depending on the use for which they are intended and the positions which they are to occupy. Nails are sold as a rule by the hundredweight, although occasionally they are sold by the thousand. The larger sizes of nails are cheaper per hundredweight than the smaller sizes, because in their manufacture less work is required to convert a given quantity of metal into nails. The different forms of nails in use receive their distinctive names from the shape of the head, but a more general classification is that based on the methods of manufacture employed to produce them. According to this latter classification there are *wrought, pressed, cut, cast,* and *wire nails.*

3. Wrought Nails.—In times past, the only nails to be had were **wrought nails** made by hand of wrought iron. Hand-forged nails may still be obtained in the larger sizes ; they are tougher and stronger than other kinds and will bear clinching. The hand-made nails are, of course, much more expensive than those made by machinery, and for that reason are seldom used except in the best work.

4. Pressed, or Machine-Wrought, Nails. — The majority of wrought-iron nails in common use are what are known as **pressed, or machine-wrought, nails.** These are pressed into shape by grooved rollers while the metal is red hot ; on removal from the rollers, the strips are cut up into the desired lengths and the heads are formed by a die.

5. Cut Nails.—Nearly all **cut nails** used at the present time are made from sheet steel, a small percentage only being manufactured of iron, for which the makers charge a slightly higher price. The iron or steel is first rolled into sheets, the thickness of which is equal to the thickness of the nail ; it is then cut into strips as wide as the nail is long. This strip of metal is

fed into the nail machine and sheared off in tapering strips having the form of the nail, when it is seized by clamps that

TABLE I

STANDARD WIRE AND SHEET-METAL GAUGES AND THEIR DECIMAL EQUIVALENTS OF AN INCH

Gauge Number	English Imperial Legal Standard (S.W.G.)	Birmingham (B.W.G.) or Old English Standard	American New Legal Standard Plates Only	Brown & Sharpe American Standard
0000000	·500		·500	
000000	·464		·469	
00000	·432		·438	
0000	·400	·454	·406	·460
000	·372	·425	·375	·410
00	·348	·380	·344	·365
0	·324	·340	·313	·325
1	·300	·300	·281	·289
2	·276	·284	·266	·258
3	·252	·259	·250	·230
4	·232	·238	·234	·204
5	·212	·220	·219	·182
6	·192	·203	·203	·162
7	·176	·180	·188	·144
8	·160	·165	·172	·129
9	·144	·148	·156	·114
10	·128	·134	·141	·102
11	·116	·120	·126	·091
12	·104	·109	·109	·081
13	·092	·095	·094	·072
14	·080	·083	·078	·064
15	·072	·072	·070	·057
16	·064	·065	·063	·051
17	·056	·058	·056	·045
18	·048	·049	·050	·040
19	·040	·042	·044	·036
20	·036	·035	·038	·032
21	·032	·032	·034	·029
22	·028	·028	·031	·025
23	·024	·025	·028	·023
24	·022	·022	·025	·020
25	·020	·020	·022	·018
26	·018	·018	·019	·016
27	·016	·016	·017	·014
28	·015	·014	·016	·013
29	·014	·013	·014	·011
30	·012	·012	·013	·010
31	·012	·010	·011	·009
32	·011	·009	·010	·008
33	·010	·008	·009	·007
34	·009	·007	·009	·006
35	·008	·005	·008	·006

hold it just long enough for the heading hammer to strike the blow that forms the head.

6. Cast Nails.—Nails formed by pouring molten metal into moulds are called **cast nails.** They are brittle and seldom used, except where there will be little stress. A short thick form is used to some extent as a tile peg.

7. Wire Nails.—The term **wire,** or **French, nail** is applied to nails made from drawn wire or wire rods. Since their introduction some years ago, wire nails have become decidedly popular, and in some localities are used in preference to the old-style cut nails, owing to the fact that there are a greater number to the pound. Wire nails are more liable to rust than cut or wrought nails, and are consequently not so durable in damp situations; they also have less holding power and more must be used to obtain the same strength.

The gauge of wire nails is the size of the wire from which the nails are formed. The different wire and sheet-metal gauges and their decimal equivalents of an inch are given in Table I. The special wire gauge commonly used to indicate the size of the nail is the Birmingham.

FORMS OF NAILS

8. Examples of Nail Heads.—In Fig. 1 (*a*), (*b*), (*c*), and (*d*) are shown the heads characteristic of the various classes of nails; in the illustration, the heads are drawn to a large scale. At (*a*)

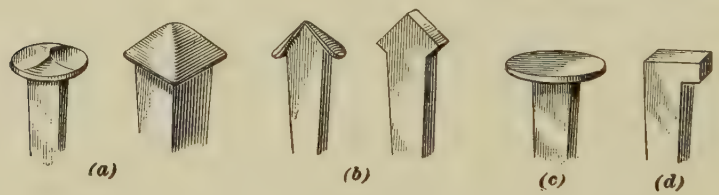


FIG. 1

are shown two types of *rose nails,* which have heads somewhat raised. Two types of *clasp nails* are shown at (*b*); these nails have heads that project downwards in such a way as to grip the

wood, the wrought-iron variety shown at the left possessing this characteristic in a marked degree. The flat circular head shown at (*c*) is that of a *clout nail*; at (*d*) is shown a *billed head* characteristic of the *brad*. The word *spike* is loosely used to designate large nails; they are generally rose-headed. The length at which nails begin to come under the heading of spikes is not accurately defined, but it may be assumed to be about 4 inches.

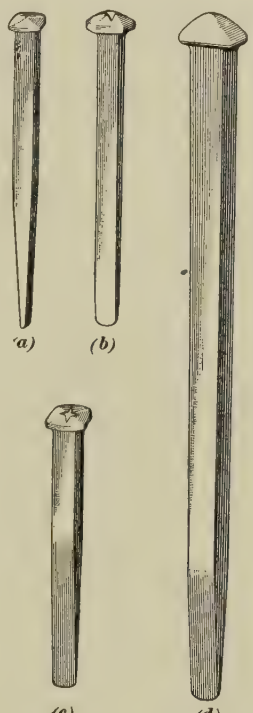


FIG. 2

9. Rose Nails.—In Fig. 2 are shown examples of **rose nails**: At (*a*) is shown a cut-steel rose nail, which may be obtained in lengths of from 1 to 6 inches. A patent wrought rose nail is shown at (*b*); this nail may be had from $1\frac{1}{4}$ to 6 inches long. The flat, pointed, patent rose nail at (*c*) may be obtained, wrought in lengths from $1\frac{1}{4}$ to 6 inches, but a lighter quality is to be had in lengths of 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, and 2 inches, while steel nails of this kind range in length from $1\frac{1}{2}$ up to $4\frac{1}{2}$ inches and even longer. The two qualities last named can also be obtained *galvanized*. The wrought-iron rose spike shown at (*d*) is made in lengths ranging from $3\frac{1}{2}$ to 12 inches.

FIG. 3

10. Clasp Nails. — The nails illustrated in Fig. 3 (*a*), (*b*), and (*c*) are known as **clasp nails.** That shown at (*a*) is a cut-steel clasp nail made in lengths of from 1 to 6 inches; that at (*b*) is a fine wrought clasp nail ranging from 1 to $3\frac{1}{2}$ inches in length; and that at (*c*) is a cut-steel clasp ranging from 1 to 6 inches.

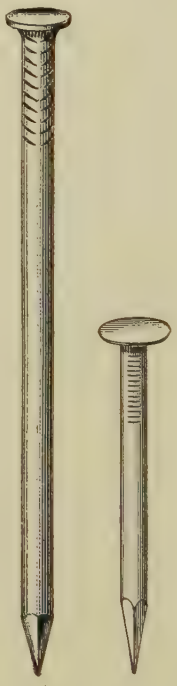
11. Clout Nails.—A typical **clout nail** is illustrated in Fig. 4. Fine wrought and strong wrought nails of this description may be obtained in various lengths from $\frac{3}{4}$ inch to 2 inches. Clout nails are used for securing thin materials, such as sheet work; the small sizes are known as **tacks.** Copper clout nails are used for nailing sheet lead or copper, and copper, zinc, composition, and galvanized clouts are used for fastening pales to the arris rails in fencing. The smaller sizes usually have sharp points and the larger sizes chisel points.

Fig. 4

12. Brads.—In Fig. 5 is illustrated a **brad** of cut steel, such as may be obtained in lengths of from 2 to 4 inches; it is used for nailing floor boards and in other similar work. A smaller nail of the same general form, but made in lengths of from $\frac{1}{2}$ inch to 3 inches, and known as a joiners' brad, is used for securing mouldings and in other joiners' work. Glaziers' brads, or **sprigs,** are short nails without heads of any kind; they are used for securing panes of glass. The word brad is used loosely for light joiners' nails, and is also applied to oval wire nails.

Fig. 5

13. Forms of Wire Nails.—In Fig. 6 (*a*) is shown an ordinary wire nail. Wire clouts may also be obtained, and at (*b*) is shown a wire slate nail which may be obtained plain or galvanized in sizes from $1\frac{1}{4}$ to 3 inches. Wire nails of oval section may also be obtained; they are known as **oval wire brads.** Their lengths and gauge sizes are given in Table II; in many cases two sizes are given for each length; for oval nails, the gauge numbers for the greater and less diameters are given.



(*a*) (*b*)

Fig. 6

TABLE II

SIZES OF WIRE NAILS

Length Inches	Gauge Number Round		Gauge Number Oval	
$\frac{1}{2}$			20 × 16	
$\frac{5}{8}$			19 × 15	
$\frac{3}{4}$	17		18 × 14	
1	16	15	17 × 13	
$1\frac{1}{4}$	15	14	17 × 13	16 × 12
$1\frac{1}{2}$	14	13	16 × 12	14 × 10
$1\frac{3}{4}$	13	12	16 × 12	14 × 10
2	12	11	16 × 12	13 × 9
$2\frac{1}{4}$	10		12 × 8	
$2\frac{1}{2}$	11	10	12 × 8	
3	11	10	10 × 6	
$3\frac{1}{2}$	8		10 × 6	
4	7		8 × 4	
5	5		8 × 4	
6	4		7 × 3	

14. **Special Nails and Spikes.**—Three special forms of nails are illustrated in Fig. 7. At (*a*) is shown a wrought-iron rain-water-pipe nail; it is made from $2\frac{1}{2}$ to 4 inches long, and over. A malleable-iron weather-tiling nail is illustrated at (*b*); such nails vary in length from $1\frac{1}{2}$ to 3 inches. At (*c*) is shown a cast-iron tile peg, such as may be had in lengths of from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches.

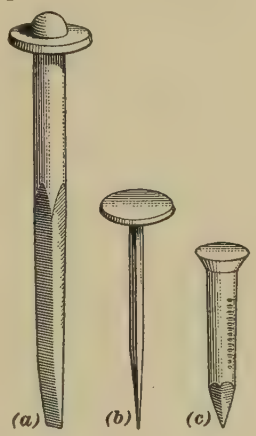


FIG. 7

15. In Fig. 8 are shown various forms of metal fasteners which are used in the same manner as nails. Two forms of wrought-iron **staples** are shown at (*a*). The square form may be had $3\frac{1}{2}$ inches by $1\frac{1}{2}$ inches, $3\frac{1}{2}$ inches by $1\frac{3}{4}$ inches, and $3\frac{1}{2}$ inches

by $2\frac{1}{2}$ inches; the curved form ranges from 1 to 6 inches in length. At (*b*) is illustrated a wrought-iron **holdfast,** made in lengths ranging from 3 to 8 inches. A wrought-iron **wall hook** is shown at (*c*); it is made from 3 to 12 inches long. A **dog-**

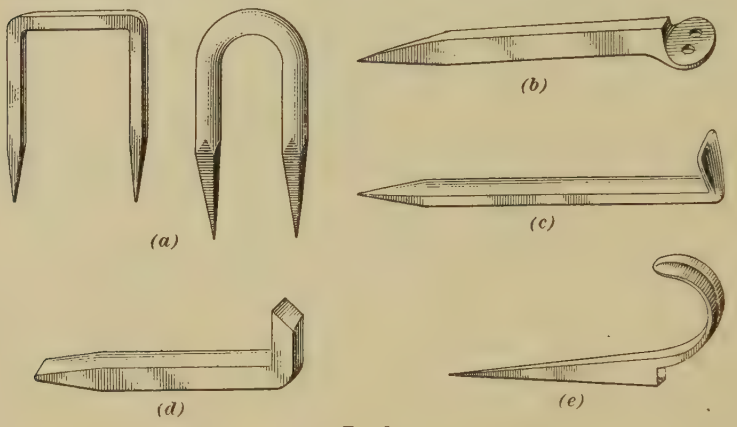


Fig. 8

spike is illustrated at (*d*); the usual sizes are $2\frac{1}{2}$ inches by $\frac{5}{16}$ inch, 3 inches by $\frac{5}{16}$ inch, and 3 inches by $\frac{3}{8}$ inch. At (*e*) is shown a wrought **pipe hook,** which can be obtained in lengths of from $\frac{1}{4}$ inch to 4 inches.

16. Galvanized Nails and Spikes.—Nails and spikes, either cut or wire, that have been dipped into molten zinc and become coated with this metal are termed **galvanized.** By this process they are rendered practically rust-proof. Galvanized cut or wire nails can be obtained in the same sizes and types as ordinary nails, and if merchants do not regularly stock them, they will, as a rule, have them galvanized to order. In order to secure durability, it is advisable to use galvanized nails in places that are exposed to dampness, as in slating, in fence building, or in structures erected near the seashore, as it has been found that ordinary nails rust through in such places in a few years. The galvanized nails cost from 7s. to 12s. more per hundredweight than the plain cut or wire nails.

17. Brass, Copper, Zinc, and Composition Nails.—Nails made of brass, copper, zinc, and composition are occasionally used for

special purposes; for instance, copper or zinc nails may be used to nail slates and tiles. However, copper is rather expensive to be used for such purposes, and zinc is too soft to be of any great value as a nail material. When, for any reason, a material other than iron or steel is required, composition nails are generally used.

SCREWS AND BOLTS

SCREWS

18. Screws Used in Woodwork.—The ordinary **wood screw,** which is one of the staple articles of ironmongery, is very necessary in the application of all builders' ironmongery about the building. Except in some lines of cheap or rough unfinished goods, manufacturers now pack with all ironmongery screws that match the finish of the goods. The various types of screws now on the market are illustrated in Fig. 9, and the common types, with flat, round, oval, and raised heads, are easily procured.

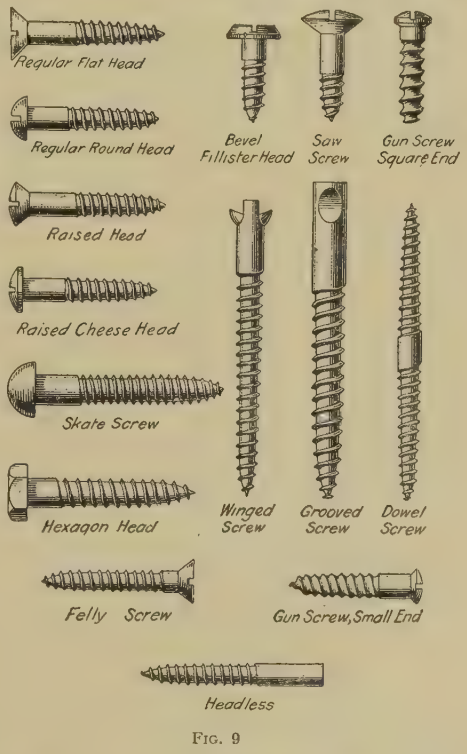


FIG. 9

19. It should be borne in mind that, although the term *iron* continues to be used as the trade description, all so-called iron screws are now made of mild steel. Iron

screws are made with flat, round, and oval heads, and the following finishes: bright, blued, japanned, tinned, galvanized, bronze-plated, brass-plated, coppered, silvered, and nickel-plated. The most usual brass finish is the natural colour of the metal, but brass screws may be obtained burnished and lacquered. Screws are also stocked in German silver and copper, and can be obtained to order in gunmetal and aluminium. For brass screws securing joinery that may require to be removed occasionally, **brass cups** are inserted in the woodwork to fit the heads of the screws. Flat-headed screws are always measured for length from the point to the top of the head; screws with raised heads are measured from the point to immediately under the head. The diameters of screws are always measured directly under the head, and are always given in numbers of the screw gauge. The numbers vary in sequence, going consecutively from 0 to 18, inclusive, and from 20 to 32 in even numbers only. Gauges from 0000 to 1, inclusive, increase by ·003 inch, and from 1 to 18, inclusive, by ·014 inch; above 18 the increase is ·028 inch.

20. Two special forms of screws for use in woodwork are illustrated in Fig. 10 (*a*) and (*b*). That shown in (*a*) is a **coach**

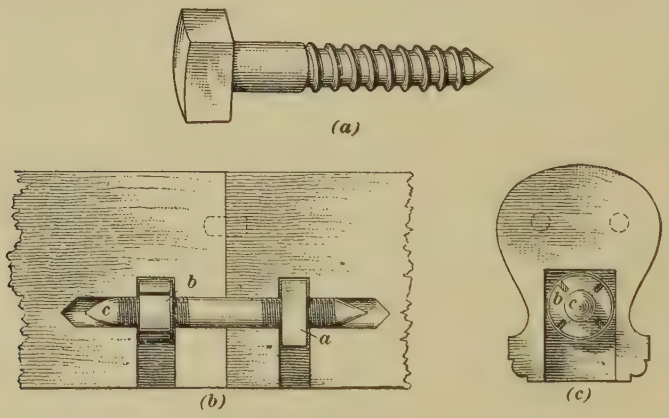


Fig. 10

screw, a large and heavy form of screw used in heavy woodwork. The head is square and the screw is driven by means of a wrench, or spanner. A **hand-rail screw** is shown at (*b*); it is used for

connecting two adjoining parts of a hand rail. The screw is threaded at both ends, and is placed in holes bored in both parts of the hand rail to be joined. A square nut is put over the bolt at *a*, and this nut cannot turn ; at *b*, a round nut is screwed on. On the surface of this round nut are slots into which a screwdriver may be inserted, as the space will not permit the insertion of a spanner. The screwing up of this nut draws the two parts of the hand rail together. In (*c*) is shown a section through the hand rail ; *c* is the hand-rail screw and *b* the slotted nut upon it.

21. Screws Used in Metal Work.—The screws used in metal work are of the type shown in Fig. 11, and are known as **set-screws.** Such a screw is of the same diameter throughout, and the hole which is to receive it must be exactly of the right bore and have a thread worked on it which shall be the exact counterpart of the thread on the screw. Screws used for metal work

Fig. 11

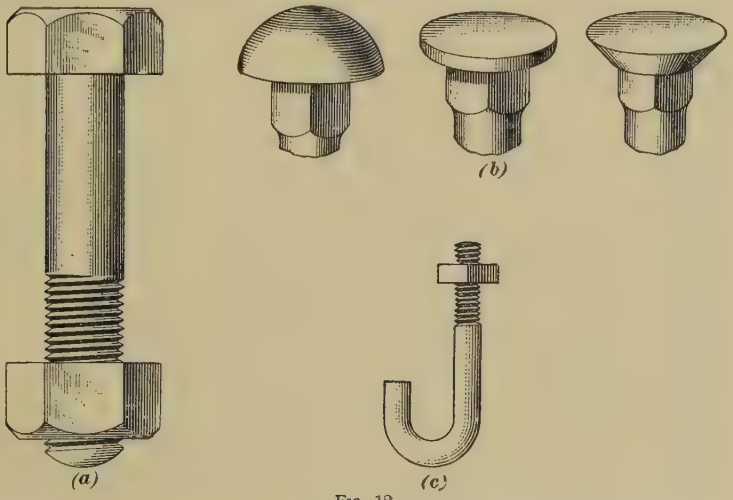


Fig. 12

are made to a standard thread, usually the Whitworth thread.

BOLTS

22. Bolts and Nuts.—The ordinary form of bolt and nut is shown in Fig. 12 (*a*). The bolt has a head formed on one end and a nut screwed on the other; the head and nut may be hexagonal or square, and the thread should be of some recognized standard. Three other forms of heads that may be applied to bolts are shown at (*b*). That to the left is a **cup head**, the next is a **cheese head**, and the one at the right is a **countersunk head.** At (*c*) is shown a **hook bolt**, used to secure corrugated-iron roofing to purlins. Galvanized bolts of this kind can be obtained in lengths of 2, 3, 4, 5, and 6 inches, measured from inside the hook to the end of the screw.

Fig. 14

SASH WEIGHTS

23. Cast-Iron Weights.—The term **sash weight** is applied to a counterweight used for balancing double-hung, or sliding, sashes. These weights are generally very rough, being made from either the poorest iron or waste iron. The stock sizes are usually long and cylindrical in form, from $1\frac{3}{8}$ to $2\frac{1}{4}$ inches in diameter, have an eye cast in the upper end, as shown in Fig. 13, and weigh from 2 to 30 or 40 pounds, the weight determining the length of the sash weight. In Table III are given the weights, diameters, and lengths of sash weights as they are generally furnished to the trade, although it is almost impossible to give these data with any degree of accuracy, as the different manufacturers vary the diameters of the weights slightly, and this changes the length measurement. Square weights or rectangular or oval weights can easily be procured at small additional cost. Heavier weights of square section can be had from stock from 10 to about 30 pounds weight.

Fig. 13

24. Lead Weights.—The weight of lead is about 80 per cent. greater than of cast iron; hence, lead sash weights must be resorted to where the construction of the pockets is too narrow to permit the use of iron weights, or where heavy plate glass is used. They are also used in cases where the sashes are very wide and low, as here a short weight must be used in order to obtain the necessary travel for the sashes.

TABLE III

WEIGHTS, DIAMETERS, AND LENGTHS OF SASH WEIGHTS

Weight Pounds	Diameter Inches	Length Inches	Weight Pounds	Diameter Inches	Length Inches
4	$1\frac{3}{16}$	$14\frac{5}{8}$	12	$1\frac{11}{16}$	23
$4\frac{1}{2}$	$1\frac{3}{8}$	13	$12\frac{1}{2}$	$1\frac{3}{4}$	23
5	$1\frac{3}{8}$	$14\frac{1}{8}$	13	$1\frac{3}{4}$	$23\frac{1}{4}$
$5\frac{1}{2}$	$1\frac{7}{16}$	$13\frac{5}{8}$	$13\frac{1}{2}$	$1\frac{3}{4}$	$23\frac{1}{2}$
6	$1\frac{7}{16}$	$14\frac{3}{4}$	14	$1\frac{13}{16}$	$22\frac{1}{8}$
$6\frac{1}{2}$	$1\frac{7}{16}$	16	$14\frac{1}{2}$	$1\frac{13}{16}$	$22\frac{3}{4}$
7	$1\frac{9}{16}$ and $1\frac{7}{16}$	$15\frac{5}{8}$ and $17\frac{1}{2}$	15	$1\frac{7}{8}$	$23\frac{1}{4}$
$7\frac{1}{2}$	$1\frac{1}{2}$	$18\frac{1}{2}$	$15\frac{1}{2}$	$1\frac{15}{16}$	$23\frac{1}{8}$
8	$1\frac{1}{2}$	$18\frac{3}{4}$	16	$1\frac{7}{8}$	$23\frac{1}{4}$
$8\frac{1}{2}$	$1\frac{1}{2}$	20	$16\frac{1}{2}$	$1\frac{15}{16}$	$23\frac{1}{4}$
9	$1\frac{1}{2}$	21	17	$1\frac{7}{8}$ and 2	$27\frac{1}{8}$ and 23
$9\frac{1}{2}$	$1\frac{5}{8}$	$18\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{13}{16}$	$28\frac{1}{4}$
10	$1\frac{5}{8}$	$19\frac{1}{2}$	18	$1\frac{13}{16}$	$28\frac{7}{8}$
$10\frac{1}{2}$	$1\frac{11}{16}$	20	$18\frac{1}{2}$	$1\frac{7}{8}$	$28\frac{1}{2}$
11	$1\frac{11}{16}$ and $1\frac{5}{8}$	21 and $22\frac{3}{4}$	19	$1\frac{7}{8}$	$28\frac{3}{4}$
$11\frac{1}{2}$	$1\frac{11}{16}$	$22\frac{3}{4}$	$19\frac{1}{2}$	$1\frac{15}{16}$	$28\frac{5}{8}$
			20	$1\frac{7}{8}$	$31\frac{1}{4}$

Lead weights can be procured in either round or square shapes, and of any diameter or measurement to suit existing conditions, but they are generally made to special order. A wrought- or malleable-iron eye, or fastening, for applying the cord or chain is usually inserted at the top. The cost of lead weights, however, is generally 5 times as great as that of iron weights.

25. Sectional Sash Weights.—There is a form of sash weight known as the **Walda sectional weight,** which is illustrated in Fig. 14. This weight, as will be observed, is so arranged that units or sections may be detached or added, as desired, to diminish or to increase the weight. Such a weight can be nicely adjusted to counterbalance any sash, and has the advantage over the cast-iron weight in that each part is interchangeable and no mistake can be made in ordering, as the necessary weight for any sash can be made up on the site.

FINISHED IRONMONGERY

MATERIALS AND FINISHES

26. Metals Used in Ironmongery Manufacture.—The metals chiefly used in manufacturing the products of the smiths' art are iron and steel, and the copper-zinc and copper-tin alloys known as brass and bronze. Iron remains the chief material of construction for most of the cheaper articles of ironmongery, while brass and bronze are more generally used for *destructible*, or wearing, parts and the finer and more elaborate decorative work. These alloys also adapt themselves admirably to the great variety of finishes that are now in vogue. Iron is also used considerably for elaborate decorations in wrought and cast designs.

27. Stock and Special Designs.—In recent years, manufacturers have made rapid strides in producing beautiful and elaborate fittings in the several schools of ornament and in making finishes to harmonize or contrast with special colour treatments. The principal manufacturers will also provide ironmongery and brass-foundry articles to special designs furnished by the architect.

28. Finishes.—The principal metals upon which are applied the variety of finishes now obtainable are iron, steel, brass, and bronze, of which the two latter, even in their highly polished natural state, are the most durable These metals will not rust

or corrode when exposed as will iron or steel, and when tarnished can readily be cleaned and polished.

Nearly all the fancy finishes are obtained by electroplating and acid treatment on the natural metals, the finish being sometimes lacquered to preserve it. Some of these finishes are very attractive and desirable, but, where exposed to constant usage, have not the durability of the natural metals, as they cannot be polished or cleaned without the finish being injured.

Many architects or owners purposely select applied finishes with the object in view that they will need little attention. When selections are being made for exterior purposes, or where there is likely to be excessive handling, it is best to select the darker shades. For interior purposes, the more delicate finishes may be selected as more suitable for the decorative effect; they also wear reasonably well. The variety of colours and shades of finish is exceedingly large, and the choice of colour, like that of texture, depends on the character of the design and on the personal taste of the one making the selection.

The standard finishes that can be obtained are numerous: many of them in various shades of oxidization and in from one to four different textures of surface. The most popular finishes are as follows:

Pompeian bronze	Lacquered polished brass
Green bronze	Copper
Brown bronze	Oxidized copper
Florentine bronze	Nickel
Ormolu	Silver
Enamelled	Oxidized silver
Japanned	Gold
White metal	Bower-Barff
Polished brass	Gun-barrel brown

When a particular finish is required, it is always advisable for the architect to obtain from the manufacturer a sample finish before ordering the particular article required. Sample finishes are usually made up of small pieces of metal similar to that of which the finished article is to be made, and should give an exact representation, as regards finish, of the particular piece of ironmongery required.

HINGES AND HANGING APPLIANCES

HINGES

29. Strap Hinges. — The common wrought hinges, used to apply on the surface, for hanging doors, etc., and generally used in connection with rough work, such as bins, sheds, barns, etc., where a strong, serviceable hinge that may be easily applied is required, are known as **strap hinges.** They are constructed of wrought metal of various weights, according to the size of the hinge, and are stamped or cut from sheet metal, with *knuckles*, or sockets for the pins, formed on the strap; the pins passing through the knuckles are well riveted. There are several kinds of light and heavy strap hinges.

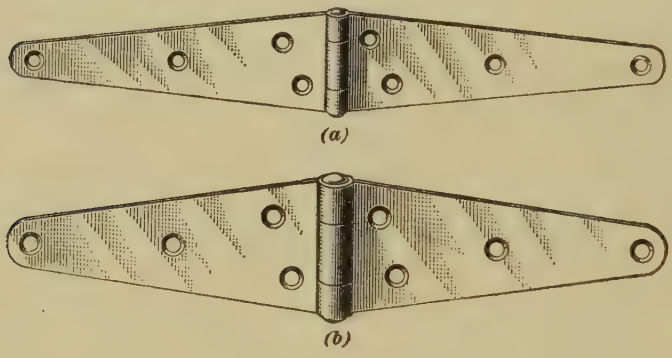


FIG. 15

The **light strap hinge,** which is shown in Fig. 15 (*a*), is so termed because of its light construction and narrow joint. This hinge is made in inch sizes, varying from 3 to 16 inches in length. By *inch size* is meant the length when the hinge is closed; thus, a 6-inch strap hinge is just under 12 inches long from end to end when opened. They are listed and sold by the pair or by the hundredweight.

The **heavy strap hinge,** which is shown at (*b*), is similar to the light hinge, but is made from heavier metal and has large dimensions at the joints, or knuckles. This type of hinge is used

where a strong, substantial hinge is required. The heavy strap hinge is made in inch sizes, from 4 to 16 inches in length. The 4- and 5-inch sizes are listed and sold by the pair, the 6-inch and larger sizes being listed and sold by the hundredweight; the larger the hinge the lower the price per hundredweight.

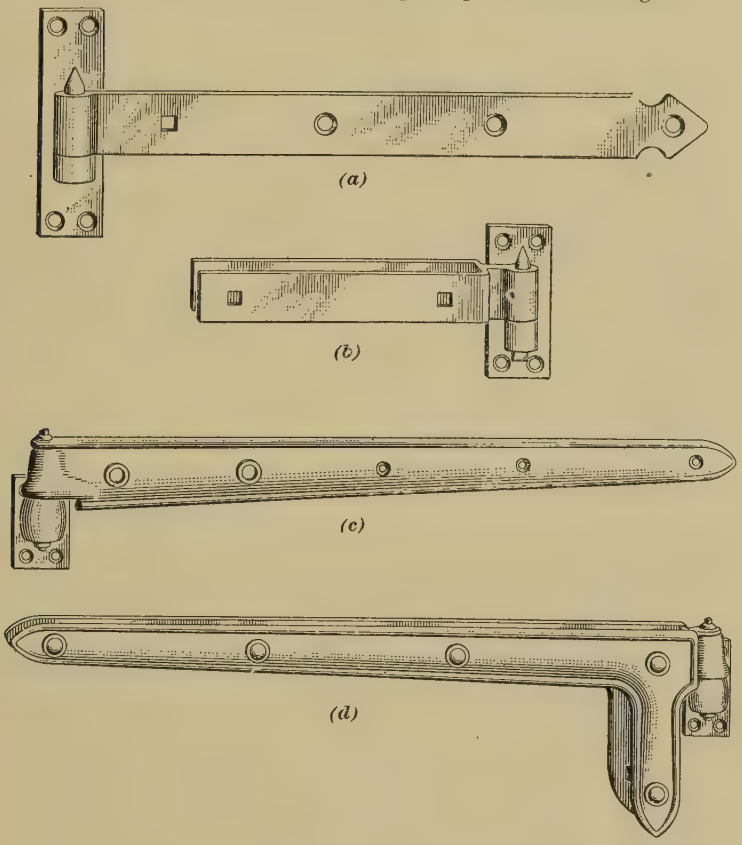


Fig. 16

30. Other hinges in common use, which are generally included under the name strap hinges, are shown in Fig. 16. At (*a*) is a hinge in common use for coach-house and other similar doors. It consists of a wrought-iron strap having a socket, or knuckle, formed at one end to work on a vertical pin attached to the plate fixed on the door frame. This sort of hanging is spoken

of as a *hook and ride*. The hinge shown at (*b*) is the same in principle as that at (*a*), but it has two wrought-iron straps between which the door is fitted. At (*c*) is illustrated a cast-iron hinge with a cup-and-ball system of hanging. The hinge at (*d*) is similar to that at (*c*), but is double. The hinges shown at (*c*) and (*d*) are known as *Collinge's patent strap hinges*. The single hinges are fixed to the door with bolts and screws, the double hinges by bolts passing through the door. The countersunk holes shown in the single hinges are for screws, and the others are for bolts. These hinges are used for coach-house, stable, and warehouse doors, and for gates.

31. T Hinges.—As will be seen from Fig. 17, **T** hinges are so called to distinguish them from the strap hinge, as well as because of their construction, which is in the form of the letter **T**. The **T** hinge is used for practically the same purpose as the strap hinge, but is superior to it in strength. **T** hinges are made in light, heavy, and extra-heavy qualities, the forms being shown in Fig. 17 (*a*), (*b*), and (*c*). In arranging the sizes of **T** hinges, the measurements are given

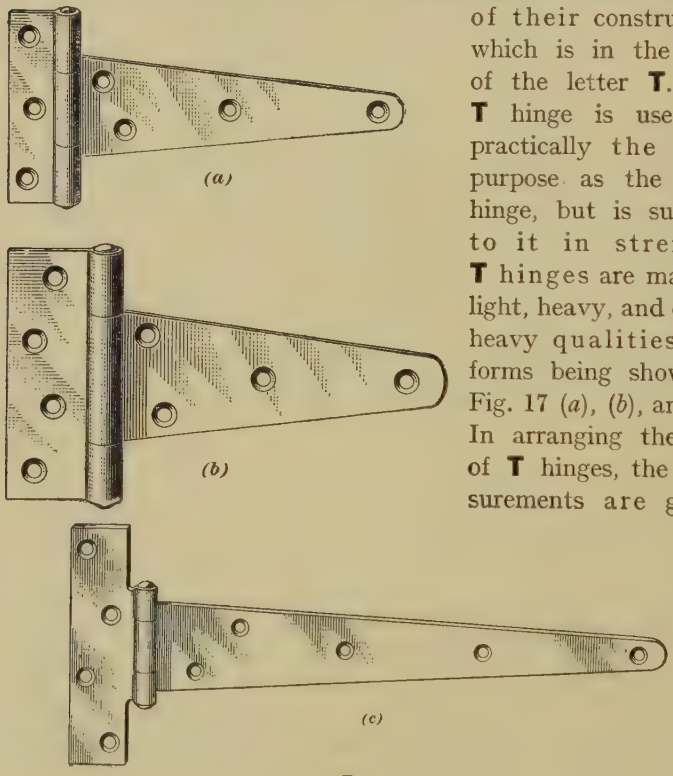


Fig. 17

for the length of the strap only ; the leaf of the hinge forming the **T** with the strap is not considered. Thus, a 6-inch **T** hinge measures 6 inches from the pin to the end of the strap leaf. The light and heavy qualities, as well as the 6- and 8-inch extra-heavy qualities, are sold by the pair, while the larger sizes of extra heavy are sold by the hundredweight. These hinges are sometimes spoken of as **cross-garnet hinges** ; but if any distinction between cross-garnet and **T** hinges is to be made, the expression cross-garnet would be used of the lighter forms and **T** of the heavier wrought hinges.

32. Butt Hinges.—In the selection of ironmongery for building purposes, no article deserves more consideration, and probably receives less, than the **butt hinge.** This type is often used for the purpose of hanging all the exterior and interior doors of buildings, and is usually secured with screws to the edge, or *butt*, of the door and to the hanging stile of the frame, the greater part of the appliance being thus unobtrusive and partly hidden from view. The butt hinge supports the entire weight of the door, and, ordinarily, is constantly in use, so that it is subjected to excessive strain and considerable wear. It is evident, therefore, that great care should be exercised in selecting hinges, so that proper sizes and qualities suitable for the purpose intended may be obtained.

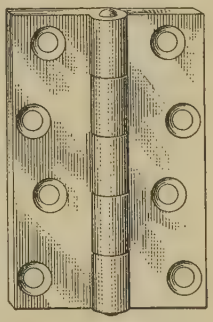


Fig. 18

33. Cast-Iron Butt Hinges.—Butt hinges, or butts, made of cast iron are used extensively in the cheaper class of buildings built for speculative purposes, in which cost is usually the controlling factor. They are made in three weights, namely, light, medium, and strong, and can be obtained from 1 inch to 6 inches across, that is, 1 inch by 1 inch to 6 inches by 6 inches when open, as in Fig. 18. Pressed, or machine-made, steel butts are also now extensively used for better-class work, and can be obtained in practically the same sizes, but the cost is slightly more than doubled.

34. Steel and Ball-Bearing Butt Hinges.—In recent years, the **steel butt hinge**, which is shown in Fig. 19, has been substituted for the cheaper cast-iron butts. The better qualities are made with ball bearings, and these are now in increasing demand for the better class of interior work. The construction of a good quality wrought-steel ball-bearing butt is shown in Fig. 20 (*a*), (*b*), (*c*), and (*d*). In this figure, (*a*) shows the hinge assembled and (*b*) the parts dissociated. At (*c*) and (*d*) are shown vertical and horizontal sections through the ball races. The great advantage of this type over other ball-bearing butts is that the door is really carried on the balls, it being impossible for the weight to come on any other part of the butt. Each butt has two ball-bearing races, as shown at *a*, *a* in (*a*), (*b*), and (*c*), and the inner cup of each is so fixed to the butt that no movement can take place without the balls revolving. The butts are made of cold-rolled steel, and to protect the surface from rusting are heavily coppered. When it is required to unhang a door to which these butts are fixed, it is done by drawing out the pin *b*, shown in (*a*) and (*b*). In (*c*) is illustrated a vertical section showing the ball race at *a* with the balls *c* and the pin *b*, while in view (*d*) is shown a horizontal section where the letters refer to the same parts as in (*c*).

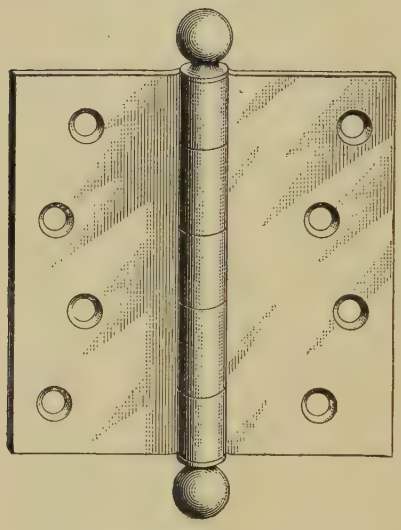
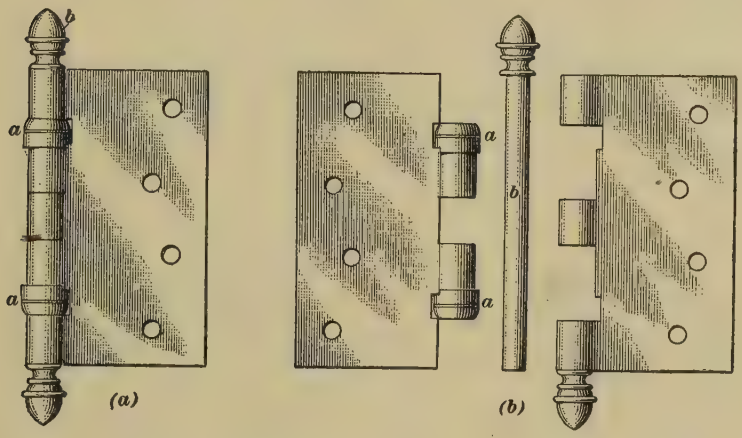


FIG. 19

Owing to the fact that they are made with smooth surfaces, the steel butt hinges can be used without grinding or buffing. These butts are stamped and formed by machinery, so that their cost is reduced to a minimum ; they also possess the advantage over the cast butt that they are practically unbreakable. The ordinary qualities are not suitable for heavy wear.

35. Cast-Bronze and Brass Butts.—For heavy work, cast-bronze butts provided with ball bearings should be used, or butts with hardened-steel bushes at the joints, as shown in Fig. 21, which is a vertical section through such a hinge, the hardened-steel



parts being shown by darker hatching, as at *a*.

All types of brass and bronze butts are made in several qualities, and it is difficult to determine the quality after they have been placed in position. It is therefore advisable for the architect or clerk of works to make a careful inspection of the ironmongery to determine whether it is furnished according to specification. Brass and bronze butts are made in light, heavy, and extra-heavy qualities, and should be provided with four knuckles. The bronze butts of the best class are now manufactured with ball bearings at the wearing joints. Bronze hinges constructed in this manner can be obtained at a cost slightly above that of the ordinary steel-bushed hinge.

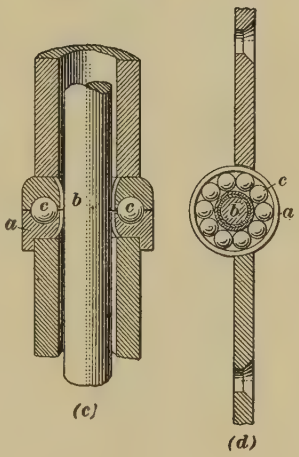


Fig. 20

Where butt hinges are exposed to the weather, as when used for exterior doors, bronze or brass butts should always be employed ; and for extra-heavy doors that are in constant use, only the extra-heavy types should be used if permanency and durability are desired.

36. Sizes of Butt Hinges.—In indicating the sizes of butt hinges, that is, the butts that are not square, two dimensions must always be given. The first dimension stated should indicate the height of the butt, and the second the width of the butt

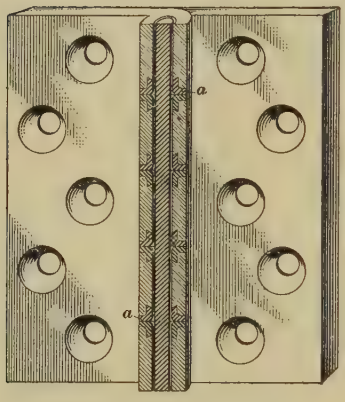


Fig. 21

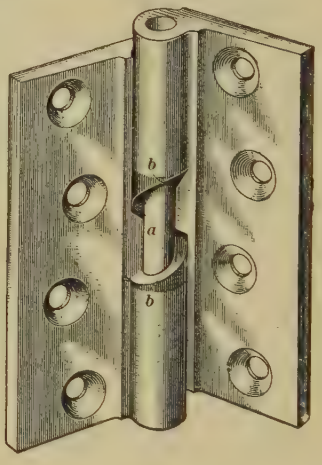


Fig. 22

when it is open. Thus, a 6″ × 5″ butt is 6 inches high and 5 inches wide when opened.

37. Rising Butts.—In Fig. 22 is shown a rising butt hinge, so constructed that as the door opens it rises, because the joint between the knuckles round the pin *a* is not horizontal, but cut in a spiral manner as at *b*. The door, when shut, is close enough to the floor to prevent draughts from passing underneath, but when opened it rises sufficiently to clear the carpet. When the door is open, its weight causes it to sink on the hinge, thus making it self-closing.

38. Projecting Butts.—In some instances hinges are used which enable the door to open clear of the jambs by some little space; these are known as **projecting butts.** In Fig. 23 is shown a form of projecting butt hinge known as a *parliament hinge.* It is used on outside shutters where the shutter is fixed in a reveal, that is, recessed back from the wall face, and it is desired that when open the shutter shall lie flat back against the wall. In Fig. 24 a form of projecting butt hinge for use on doors is shown in elevation at (*a*) and in plan at (*b*). These butts enable the door to open wider by twice the distance *a* in (*b*) than an ordinary butt would, and an instance of their use is often to be seen on railway-carriage doors. The edge near the door lock must be bevelled when this type of hinge is used.

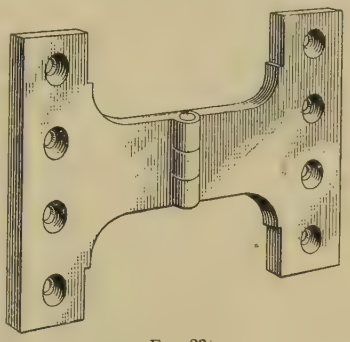


FIG. 23.

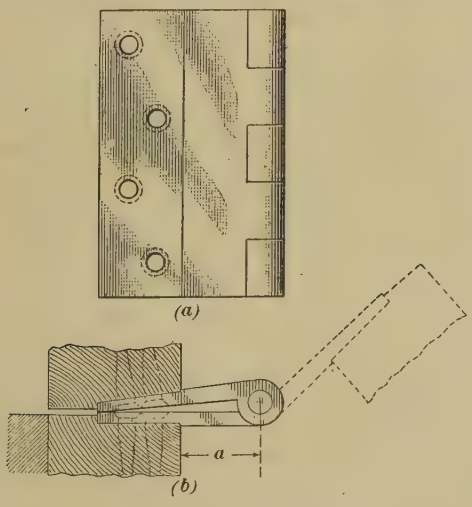


FIG. 24

39. Inside-Shutter Hinges.—Inside shutters are sometimes provided in the better class of domestic and other buildings, and for hanging these shutters three kinds of hinges are used, depending on the number of folds in the shutter and the manner in which they fold back on each other. Usually, the *butt* and the *back flap*, as shown in Fig. 25 (*a*) and (*b*), are used. Where the shutter has three folds, however, a *knuckle butt*, as shown at (*c*), may

be necessary. The purpose of the knuckle butt is to cause the folds to take such relative positions as will enable them, when open, to close properly into a pocket, or recess, formed in the window frame.

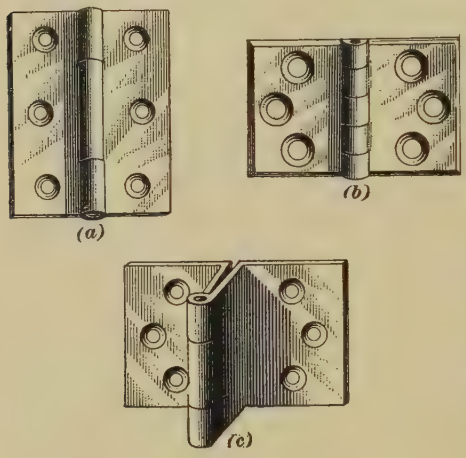


FIG. 25

40. Hinge Plates. Mediæval ironwork was the product of the blacksmith and the whitesmith, the former working with forge and hammer, and the latter with chisel and file, the material being wrought iron. The butt hinge was unknown, while the strap, or surface, hinge was in universal use ; and, as this was wholly in sight, it naturally became the subject of decoration, chiefly in outline, but occasionally in surface ornament also. With the adoption of the butt hinge for general use, the opportunity of utilizing the hinge to decorate the surface of the door disappeared, but with the modern revival of decorative art the use of constructive metal work as a feature of surface decoration for important doors was restored. This was accomplished by combining with the modern butt a surface plate that represents the strap hinge. Obviously, the width of the butt of a hinge plate should correspond with the height of the butt hinge with which it is to be used, and both should be of the same metal and finish. The other dimensions are governed by the size of the door and by taste, as is true also in the case of corner plates. A selection of typical hinge plates is given in the group of designs shown in Fig. 26.

41. Single-Action Spring Hinges.—A butt, or hinge, having a coil spring either between the knuckles or enclosed between the leaves, to close a door which opens only one way, is known as a **single-action spring hinge.** The one illustrated in Fig. 27 (*a*)

is made with a spiral spring enclosed within the casing formed by one of the knuckles. The tension on this spring can be increased by turning the collar at *a* with a pin, or bar. At (*b*) is

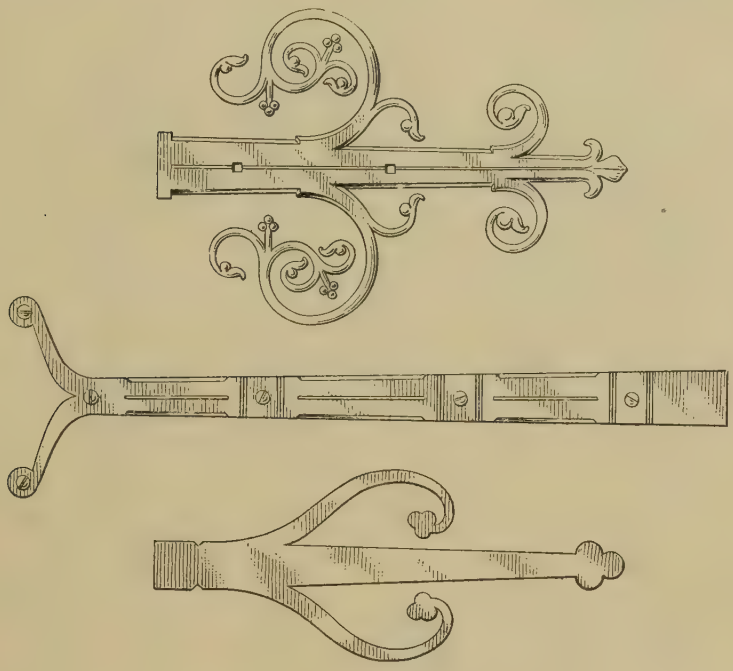


Fig. 26

shown a single-action spring hinge with a spiral spring encased between the two leaves. In operating, this spring always tends to throw the door back to its closed position.

42. Double-Action Spring Hinge.—The **double-action spring hinge** is similar in construction to a single-action hinge, except that it is arranged so that the door can swing both ways. These hinges are combined in one piece, as illustrated in Fig. 28 (*a*), (*b*), and (*c*). The plan shown at (*c*) will make the operation of these hinges clear. If the door is opened in the direction indicated by the arrow at *a* it will swing about the pivot at *c*, the plates *f* and *g* of the butt remaining flat against the jamb. If the door is opened

as shown at *b* it will turn about *d*, and the parts *e* and *f* of the butt will remain against the back of the door, only the plate *g* remaining flat on the jamb.

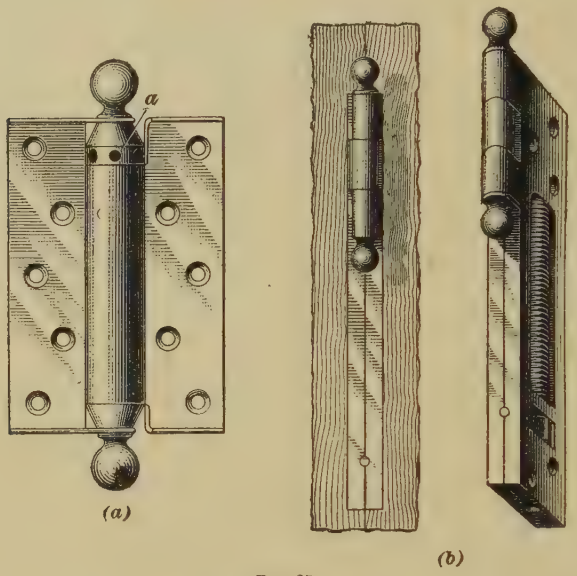


Fig. 27

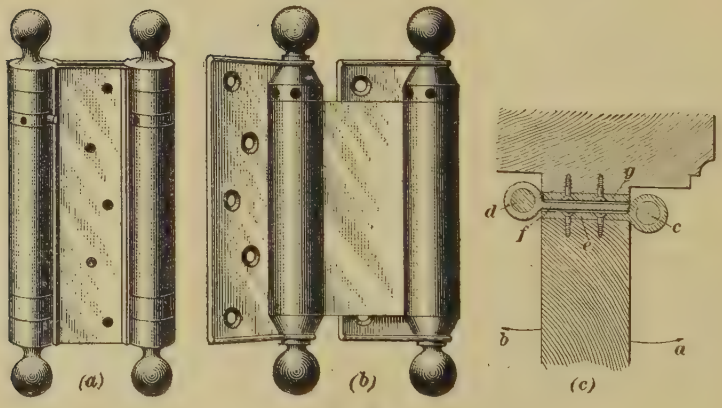


Fig. 28

Such hinges are much heavier and more costly than the single-action hinge, but they are sometimes used for entrance doors of

hotels and public buildings, and for doors between kitchen and pantry or dining-room in private residences, where a door that will swing both ways and return to a closed position is desirable. The double-action hinge is usually subjected to excessive wear and strain. Care should therefore be exercised in selecting this type of hinge; also in determining the size. It is better to have a hinge slightly larger than required than one that is too small. While double-action spring hinges made of cast iron can be obtained, the latest patterns are of steel. They may also be procured in brass or bronze, and of any desired finish to match the other fittings.

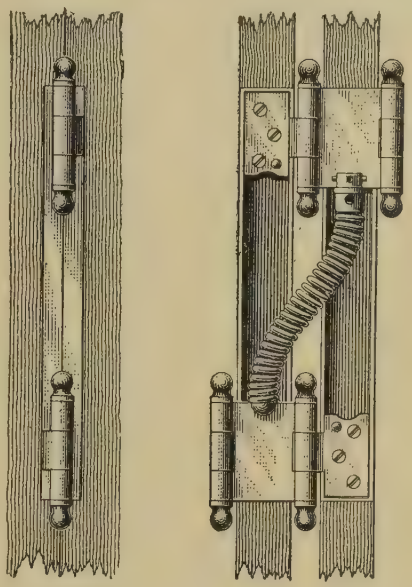


Fig. 29

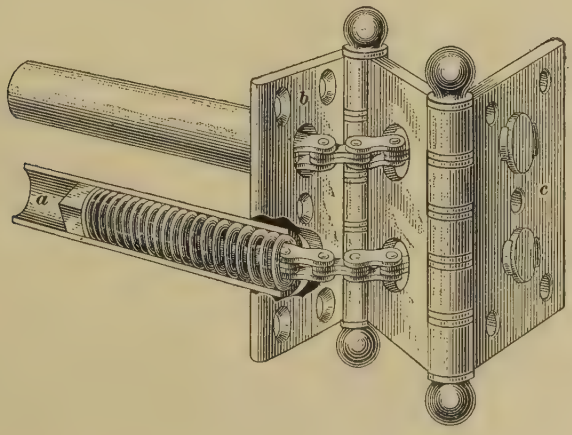


Fig. 30

43. In Fig. 29 is shown another type of double-action spring hinge which is not so compact as that illustrated in Fig. 28. This hinge, as shown, is operated by a coil spring that fits into a rabbet formed in the two leaves of the spring; thus, the coil is invisible when the door is closed, or in its normal position. This hinge obtains a good purchase on the door and jamb.

44. Another form of spring hinge for double-action doors is shown in Fig. 30. The springs at *a* are let into a mortise in the door; the plate *b* is screwed to the back of the door and the plate *c* to the jamb. The working of the hinge is similar to that just described, and the effect of the spring will be readily appreciated from a consideration of the illustration.

DOOR SPRINGS, CHECKS, AND STOPS

45. Examples of Floor Springs.—A device is made for hanging single- and double-action doors by means of pivots, or trunnions, placed at the top and the bottom. The top pivot is usually inactive; that is, it has no spring or other device, and is simply a trunnion, or pivot, with the necessary plate to engage it fastened to the edge of the door head. The bottom piece, on the other hand, is arranged with a pivot and a coil spring.

46. In Fig. 31, a vertical section through the box containing the spring at the bottom pivot of the door is shown. The plate *a* is flush with the floor; the metal shoe *b* fits round the heel of the door and is screwed to it. In the bottom of the shoe at *c* is the pivot on which the door rotates. This pivot is rigidly connected to the cam at *d*, and as the door is opened the cam, turning, compresses the spring *e*. When the door is let go, the spring, in resuming its original state, reverses the process and causes the door to shut. Other forms of floor spring are to be had, if desired.

47. Another spring device for closing single-action doors is illustrated in Fig. 32 (*a*). This is often catalogued as a **helical door spring,** though the word *helical* may be applied to any

spring of spiral form. The door is hung on ordinary butts, and on the side toward which it opens the spring is fixed. It consists of an arm *a*, which is pressed against the back of the door by

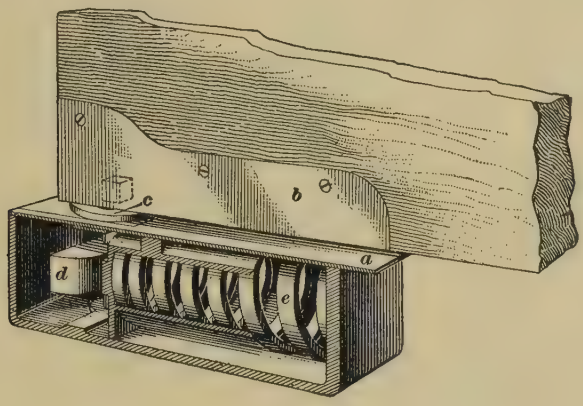


Fig. 31

a strong spring in the hinge *b* about which the arm works; this spring is attached to the door jamb. As the end of the arm at *c* moves a short distance to and fro on the surface of the door as it opens and closes, it is fitted with a small wheel

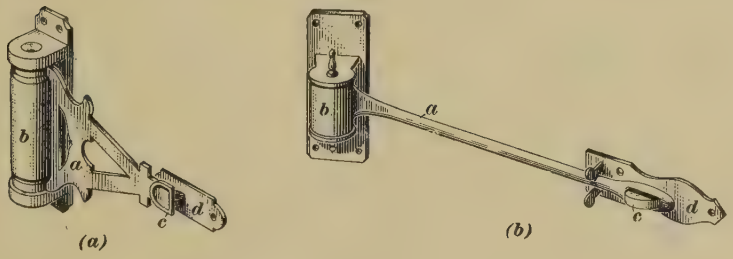


Fig. 32

which travels on a small plate *d* screwed to the door rail. At (*b*) is shown a spring of similar kind with a longer arm. This is sometimes known as a *long-tail* or *rat-tail door spring;* the letters refer to the same parts as in (*a*).

48. Two other door-closing contrivances are illustrated in Fig. 33. At (*a*) is shown the **torsion rod**, which is twisted by the action of opening the door; when let go, it closes the door in resuming its former position. It may be strengthened by increasing the amount of initial torsion; the spanner for this purpose is shown in the illustration. At (*b*) is shown an ordinary coil spring, one end of which is fixed to the door and one to the jamb. As the door is opened the twist of the spring is increased, and in righting itself the spring closes the door.

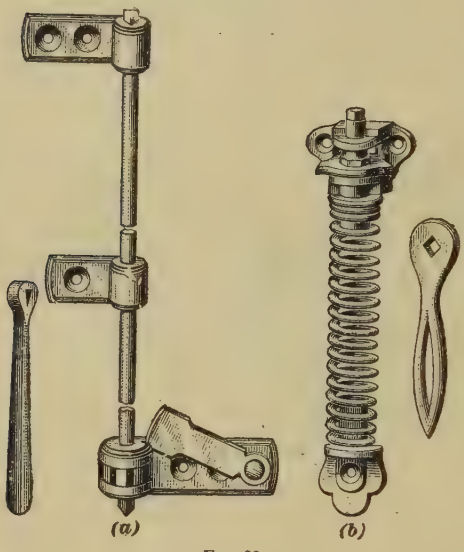


FIG. 33

49. **Door Springs and Checks.**—During recent years considerable improvement has been noticeable in the construction of the devices known as door springs and checks. The appliances that have just been described effectively close the door, but not without the unnecessary bang and slam made by the door when striking the jambs. This was overcome to some extent, however, by the introduction of the **air-check**, which depends on the use of an air cushion to resist the force of the spring. In effect, each check is a small air pump.

Prominent among the older type of air-checks is the *Eclipse*. This check is illustrated in Fig. 34. At (*a*) and (*b*) are shown two methods of applying the Eclipse air-checks. In (*a*), the spring-check that closes the door is shown at *a* attached to the door, while its lever arm is fastened to the door head. The cylinder *b* is also secured to the door, and the piston *c*, working

in the cylinder, is applied to the door head. At (*b*), the parts are differently arranged. The spring-check occupies the same relative position as shown in (*a*), its lever arm being attached at *a*,

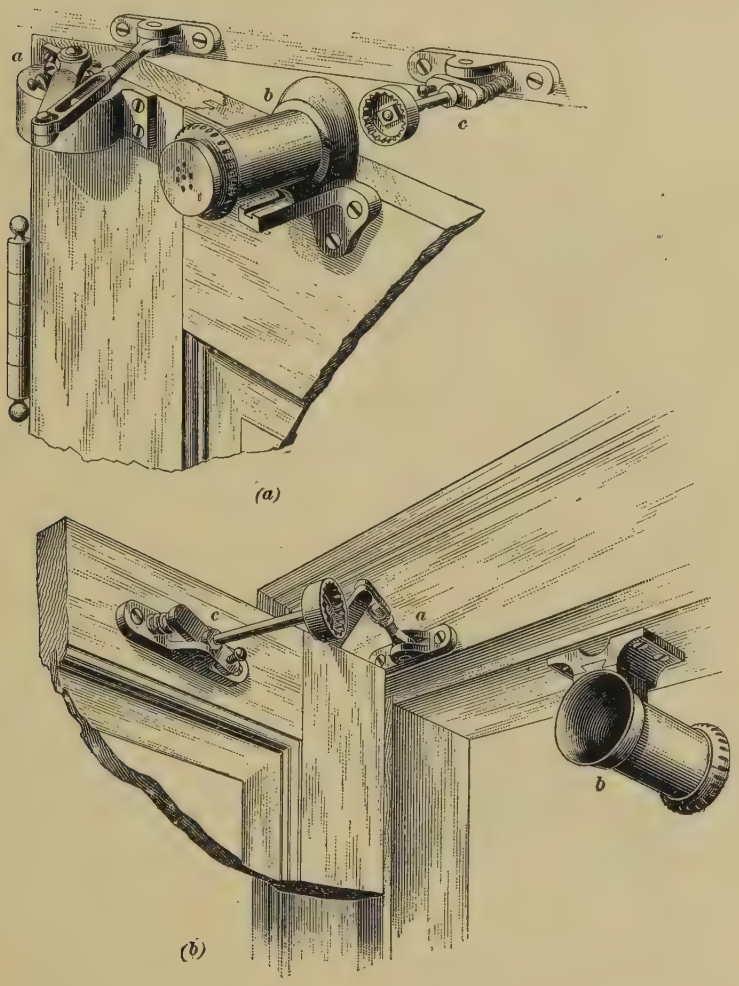


FIG. 34

while the piston *c* is fastened to the door and the cylinder *b* affixed to the head of the door frame. Either method is adapted for inside doors, but that shown at (*b*) is preferable for doors

opening outwards, on account of fewer parts being exposed, the spring-check and its lever arms, in this case, being the only parts exposed to the weather. In construction, these checks consist of a cylinder *b* with a polished interior, in which works the piston *c*. On the end of the piston there is provided a cup made of leather that has previously been soaked in oil. By the insertion of the piston into the cylinder as the door closes, there is a tendency to compress the air in the cylinder, thus forming an air cushion with air outlet at the caps. These outlets can be regulated by turning, or screwing, the cap to the right or the left, as the case may require.

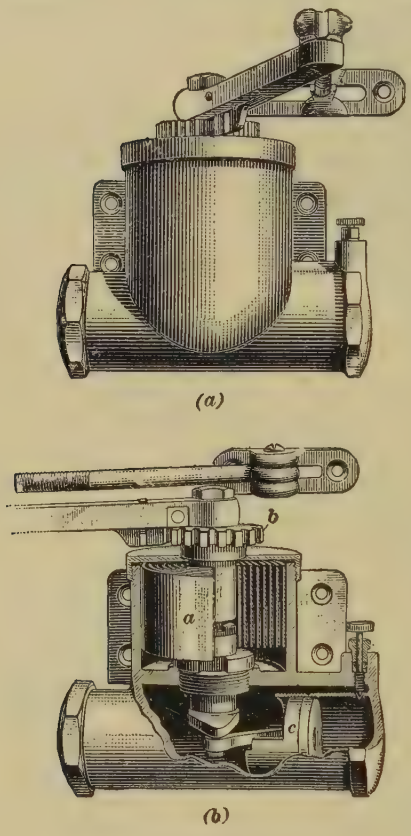
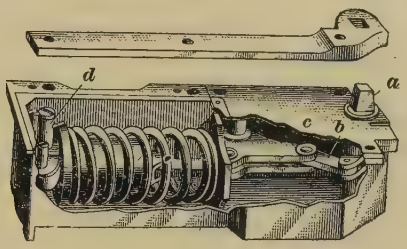


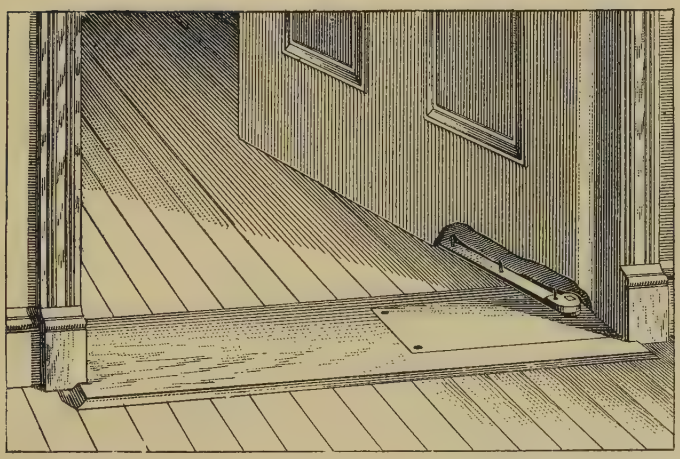
Fig. 35

50. Combined Spring and Check. — Devices of this kind, however, did not prove satisfactory until the introduction of a kind of *hydraulic combined spring and check*, which is shown in Fig. 35 (*a*) and (*b*). Here, the coil spring *a*, shown in (*b*), is enclosed in the vertical portion of the check, the regulating of the tension being accomplished by turning the ratchet sleeve *b* with a wrench made for that purpose. The check enclosed in the horizontal part consists of a metallic piston *c*, without packing, that moves in a tightly sealed metallic cylinder containing a lubricating and non-freezing liquid. The movement of the door in closing depends on the

escape of the liquid through a by-pass from one end of the cylinder to the centre, this by-pass being controlled by a small valve that may readily be adjusted to produce any desired action of the door and thus permit the door to be closed silently, with a smooth, steady motion and without rebound. This kind of door spring



(a)



(b)

Fig. 36

and check is made by several firms, and is sold under different names.

51. Floor Springs and Checks.—The principle of the door spring is also used in the combined floor springs and checks now so largely used. They have the advantage over the

mechanism just described that the door is not disfigured by the somewhat unsightly form of the appliance. All the working parts are out of sight below the floor.

In Fig. 36 is illustrated a **single-action spring hinge and check.** This spring hinge has its mechanism enclosed in a cast-iron box, which is shown in (*a*). This box, or case, is set into the floor, the top plate being made flush with the top of the floor, as shown in (*b*). The operating bar, or pivot, of the hinge has a square end, as shown at *a*, which engages with the plate secured to the bottom edge of the door, and is connected to the mechanism by means of a crank and connecting link, as at *b*. After being set into the floor, the cast-iron box or case, containing the spring, is filled with oil or other non-freezing liquid, and sealed by means of a top plate *c*. The action of the door in opening compresses the spring and operates the piston in the cylinder. The spring operating to close the door also moves the piston and forces the oil in the cylinder out through a by-pass, the flow being regulated by the adjusting screws *d*, which are on a level with the top plate. In this manner the door is closed surely but gently. Hinges of this type can be adopted without any modification of the door or frame, and are extensively used for the best class of work in public buildings, hotels, business premises, etc. For pivoting the door at the top, a top pivot and plate are provided.

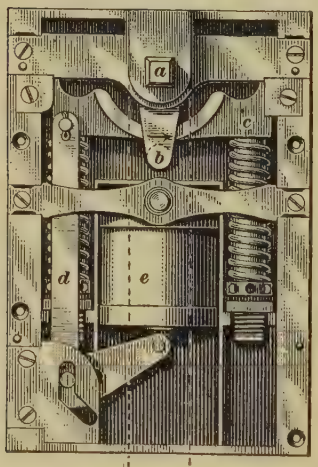


FIG. 37

52. Fig. 36 serves to illustrate the general type of these appliances, but different makers will arrange the parts differently, and every arrangement must be judged on its merits. The same general principles are also applied to the manufacture of double-action floor springs and checks, as shown in Fig. 37, which is a plan with the top plate removed, the door on pivot *a* occupying

the position shown by dotted lines when closed. When the door is opened, an eccentric cam beneath the pivot *a* moves the cradle *c* forwards and compresses both springs. The arm *b* moves with the pivot *a*, and acts as a guide for the cradle, operating the cylinder, or air-check, *e* by means of the bar *d*. When the door is released the action is reversed.

Double-action floor springs are rapidly displacing double-action spring butts. This is due to the fact that when the former method is employed the door is pivoted at the top and bottom and the weight of the door is not carried by the coils of the spring, as in the double-action spring butt. The floor type of double-action spring carries the weight of the door in the floor box, the coil performing only the function of closing the door.

53. Door Stops.—A door stop is a device for limiting the backward swing of the door. This device may also be constructed so as to perform the additional function of holding the door in an open position; it is then known as a door holder. The ordinary door stop is simply a round piece of rubber screwed to the floor, as shown at *a* in Fig. 38. This illustration shows an ordinary door stop combined with a catch which holds the door in a fixed position. The door, swinging open in the direction of the arrow at *b*, encounters the splayed surface of the catch *c*, and, pressing it down, passes over it and strikes the stop *a*. The catch then springs up behind the door and prevents its return until the catch has been pressed down by the foot, or otherwise.

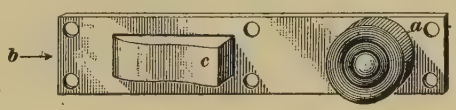


FIG. 38

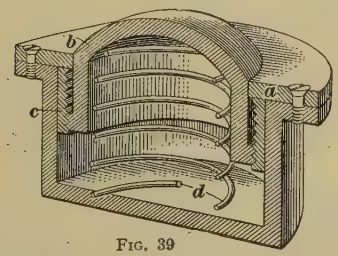


FIG. 39

Another form of door stop, made of gunmetal, is illustrated in Fig. 39. The plate *a* is fixed flush with the floor. The domed part *b* of the stop which comes in contact with the door may be adjusted by being screwed higher or lower in the socket *c*; *b* and *c* are together pressed up by a spring *d*.

SLIDING-DOOR HANGERS AND TRACK

54. In the use of sliding doors, a minimum of friction is desired in the motion of the door, and several forms of gearing are in use to reduce friction as far as possible. The gearing may

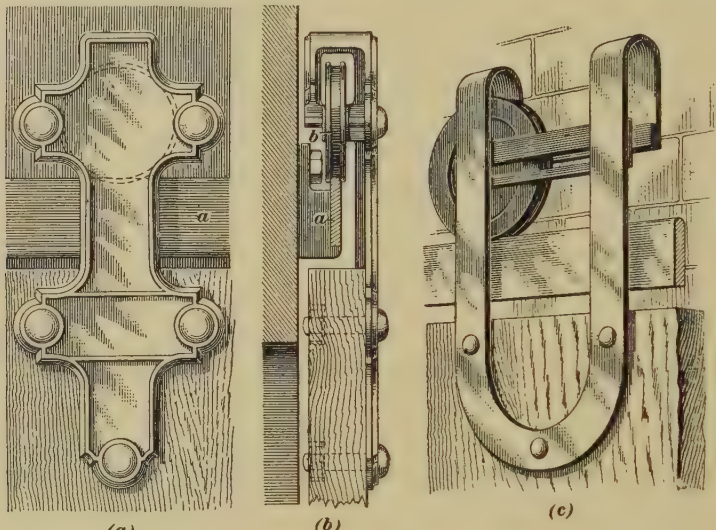


FIG. 40

be divided into two classes: the overhead trolley from which the door is hung, and the floor track runners on which the door rides. Of the first class, three kinds are worthy of description: the *Hatfield*, the *Coburn*, and the *Crittall*.

FIG. 41

55. Hatfield Patent Hangers.—In Fig. 40 (*a*) and (*b*) are illustrated **Hatfield's patent hangers.** A side and a front view of a malleable cast hanger are shown in (*a*) and (*b*), respectively. At *a* is the track or rail on which the roller *b* supporting the door moves. Two of these hangers would be required to each door. At (*c*) is shown another form of the same kind of roller, but in wrought instead of cast iron. This form of hanger may be used for

coach-house or factory doors, or wherever appearance need not be considered.

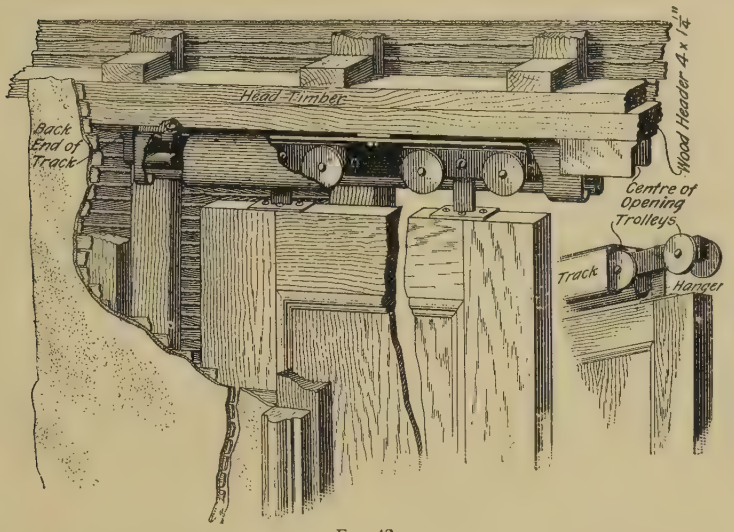


Fig. 42

56. Coburn Trolley.—Another form of overhead trolley is illustrated in Fig. 43, and is known as the **Coburn.** It is suitable for internal work, and may be used on folding partitions, as shown in Fig. 44.

The track, a typical section of which is shown in Fig. 41, is made of sheet steel, which is bent or folded into various forms, depending on the particular make. The carrier is contained in the interior of the track. The several features of this type of track and hanger are illustrated in Figs. 42 to 44.

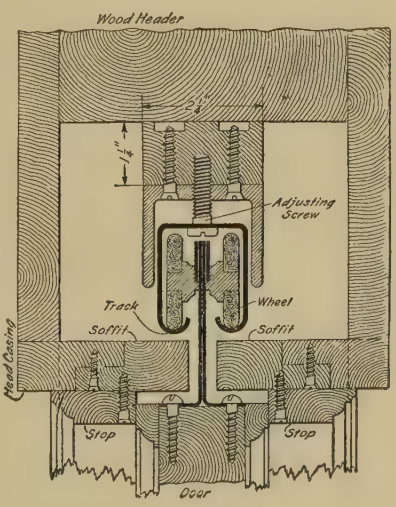


Fig. 43

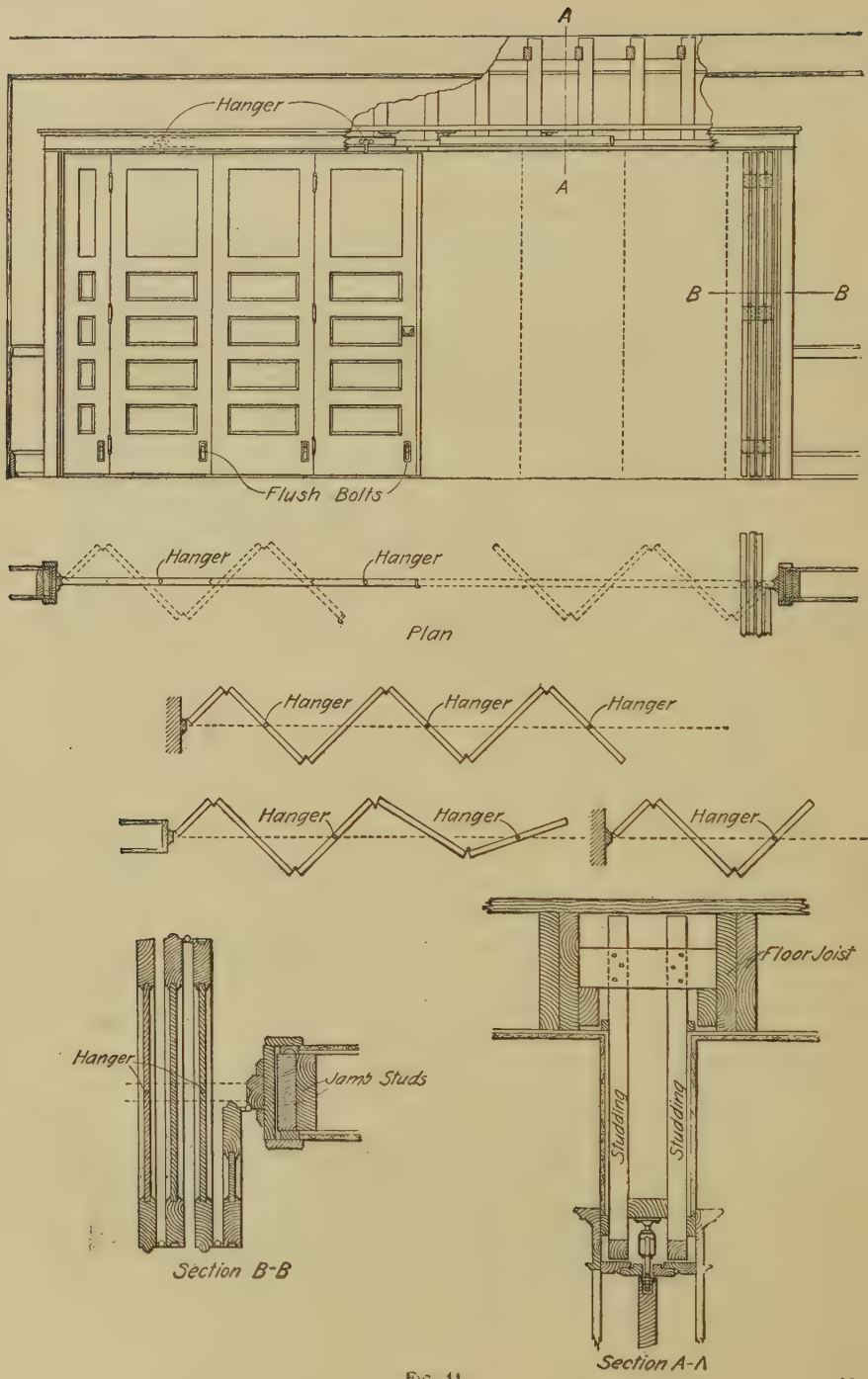

A
Hanger
A
B
B
Flush Bolts
Hanger
Hanger
Plan
Hanger
Hanger
Hanger
Hanger
Hanger
Hanger
Floor Joist
Hanger
Jamb Studs
Studding
Studding
Section B-B
Section A-A

Fig. 44

as also the method of attachment and the detail construction of the door head, or soffit, necessary to receive them.

57. Crittall Runner.—In Fig. 45 is shown the Crittall sliding ball roller, (*a*) in perspective and (*b*) in section. The plate *a*

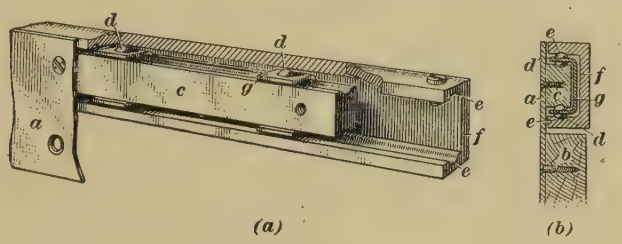


Fig. 45

is fixed to the door *b* and also to the running block *c*, which rolls on the balls at *d* moving in the grooves *e*, *e* of the casing *f*. Each pair of balls maintained in its relative position by the connecting piece *g* is free to run both in the channel runner *e* and on the block *c*, the friction on each being the same. In consequence of this, when the door is pushed a certain distance in one direction, instead of the balls remaining in their original position and the runner moving over them, or the balls retaining their position with regard to the runner and moving all the way with it, half of each of these actions takes place, and the balls move only half the distance traversed by the runner. This lessens the friction considerably. When overhead trolleys are used to carry sliding doors, a guide rail is usually provided at the bottom, which may take the form shown in Fig. 46 or may be merely a flat bar of iron running in a groove in the floor. In Fig. 46 the guide rail *a* is grooved into the floor; *b* is a wheel whose axle is fixed to the plates *c* screwed to the door *d*.

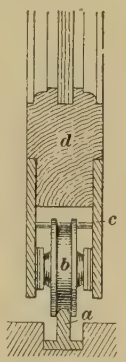


Fig. 46

58. Steel-Ball Runner.—Of the class of floor-track runners two forms are illustrated. The roller shown in Fig. 47 consists of a wrought-steel case *a* let into the bottom rail of the door and

containing hardened-steel balls *b*, which run on the track rail *c* let into the floor. Two of these runners would be required for each door and a guide rail or socket for the door at the top.

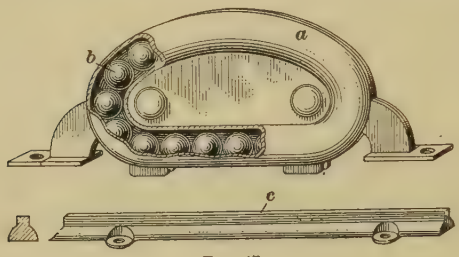


Fig. 47

59. Loose-Wheel Runner.—In Fig. 48 another form of runner is illustrated, (*a*) showing the section and (*b*) the elevation; the case *a* is let into the bottom rail of the door, and the wheel *b* runs on a rail *c* let into the floor. The axle *d* of the wheel is free to roll in the slot *e* and the wheel to roll on the rail, so that the friction is considerably reduced in a manner similar to that described in connection with the Crittall runner.

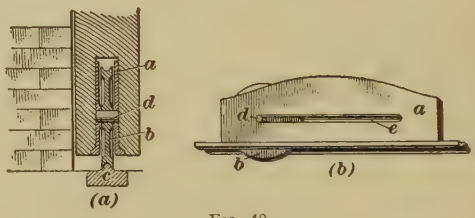


Fig. 48

60. Fire-Resisting Door Tracks.—In factory and other buildings, it frequently happens that one portion must be separated from another by brick fire-resisting walls, and that the openings in these walls are closed with fire-resisting doors, as required by the local authorities or insurance companies, so as to reduce the risk of the spread of fire. Wherever possible, these doors are made sliding and are arranged so as to close automatically, being hung on a slanting track with an incline of $\frac{3}{4}$ inch to the foot, and also counterbalanced with weights so that the door will stand at any point, as shown in Fig. 49. The cord or rope attached to the weights passes over a pulley and is attached to the door with a fusible link, as at *a*, which, in case of fire, gives way and allows the door to close automatically.

The track for these doors is best made of round-edge bar iron or tire steel, $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch, being bolted to the wall with through bolts having nuts and flanged washers on the opposite

side, and held from the wall by cast-iron track brackets. The hangers *b* are of wrought iron, $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch, provided with roller-bearing wheels and are attached to the door with at least two bolts. The binders *c* are of wrought metal, $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch, with angle flanges at back end to notch in the wall and so arranged as to grip and force the door against the wall when closed. In connection with this, a wedge is placed at

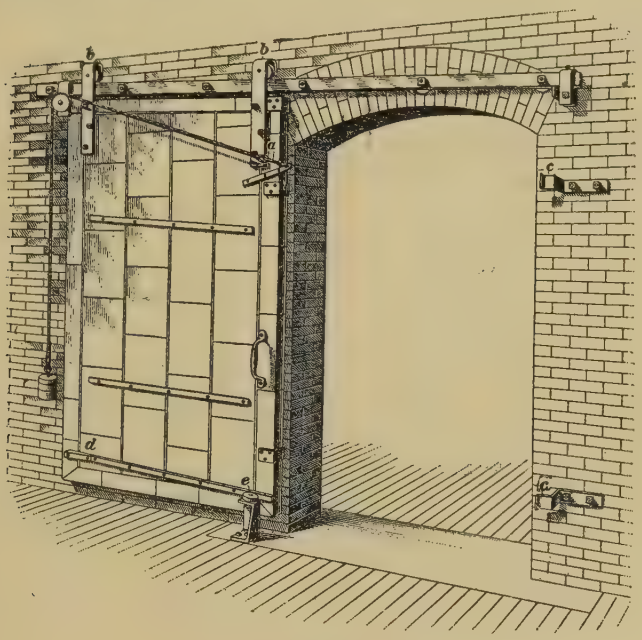


FIG. 49

the end of the lower chafing strip at *d*, and, when the door is closed, this engages with the stay roll *e* so that the door will be held close to the wall on the opposite side. Two chafing strips of $\frac{3}{4}$-inch half-oval metal are placed on the back of the door, with $1'' \times \frac{1}{8}''$ flat strips of the same length in front and bolted through the door. Shoes are also used to prevent the binders from mutilating or damaging the covering at the points that strike the binders.

GATE HINGES AND STOPS

61. Gate Hinges.—For small gates any form of strap hinge is suitable provided it is strong enough; but for large gates, such as would be placed at the entrance to a house carriage drive, hinges such as are shown in Fig. 50 would probably be adopted. The manner of fixing the hinges to the gate and post will be clear from the illustration. In case the gate had sagged, the nut *a* would be screwed up so as to draw the top of the gate

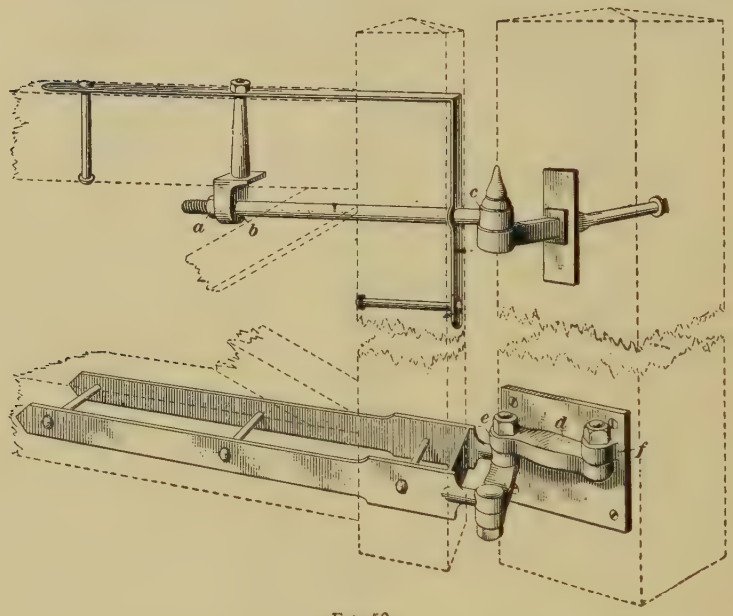


FIG. 50

nearer to the post by shortening the distance from *b* to *c*; this would lift the far corner of the gate off the ground. The bottom hinge works on much the same principle as the hinge shown in Fig. 28, and allows the door to swing both ways; it also has the advantage of being self-closing. The upper hinge has only one pivot and it is vertically over the point *d*, which lies midway between the pivots *e* and *f*. When the gate has opened one way, as shown, it hangs on the upper hinge and the pivot *e*

and so is not truly vertical, the top of the gate being inclined toward the closed position. This inclined position and the weight of the gate cause the gate to swing to. The same action takes place if the gate is opened the other way. In Fig. 51 an older form of bottom hinge, to have the same effect, is shown; the gate swings about either one or other of the vertical pins *a* or *b* according to which way it is opened, and being out of the vertical it tends to return. The part *c* is fixed to the post and the part *d* to the gate.

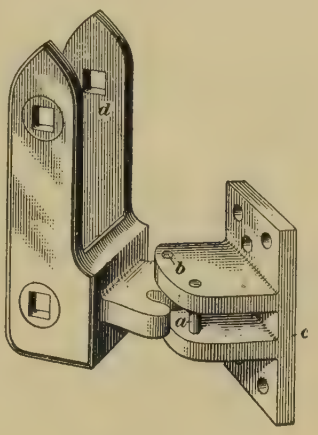


Fig. 51

62. Gate Stops.—In Fig. 52 is shown a common form of gate stop and holder. The bottom of the gate as it swings open strikes the inclined surface *a* of the weighted lever, presses it down and passes over it, but cannot pass the stop *b*. The weight *c* at the other end of the lever raises the end at *a* again, and the gate is held by the notch *d*.

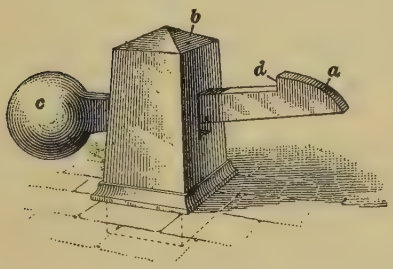


Fig. 52

Where a pair of folding gates meet, some kind of stop to hold them is necessary. This stop may be provided by means of a piece of stone or oak let into the ground; but the projection of this kind of stop above the ground surface when the gate is open is an objectionable feature. To avoid this, a collapsible cast-iron stop, as shown in Fig. 53, may be used. At (*a*), a view of the stop shows how two small metal toes, one on each gate, catch the nose of the stop and lift it up. The section (*b*) shows the stop pivoted at *a*, so that the heavy part at *b* causes the stop to fall almost flush with the ground when it is not in

use. To secure gates of this kind, a locking-bar and padlock would be used, and one of the gates would probably also be secured by a long iron stayrod engaging with an eye or staple on the back of the gate.

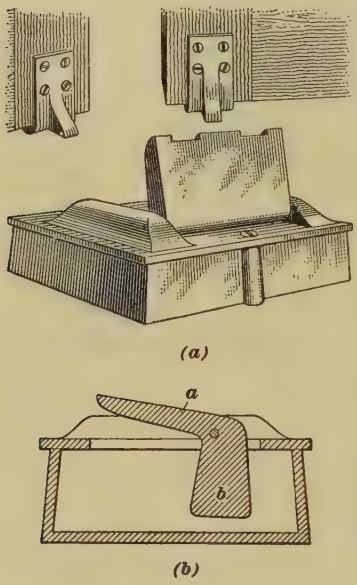


FIG. 53

LOCKS, LATCHES, AND BOLTS

LOCKS

63. Classification of Locks. In no other kind of ironmongery is there such a variety of qualities and types as there is in door locks. In general, locks may be designated as *rim* and *mortise locks*, the former being secured to the surface of the door and entirely exposed to view, while the latter are let into a mortise cut in the edge of the stile. Besides these two general kinds of locks, there are several special locks, some of which will be fully explained. As to quality, locks may be classified in three classes; namely, *common*, *medium*, and *best*. Ordinary door locks, whether rim or mortise, are worked on the same general principle.

64. Lock Mechanism.—In Fig. 54 is shown an ordinary door lock with one side removed to expose the mechanism. Through the square hole *a* a spindle passes, on to the ends of which are fixed the door handles. If the handle is turned, causing the spindle to rotate in a counter-clockwise manner, as indicated by the arrow *b*, the projecting knob *c* of the *follower*, or part turned by the handle, will draw back the *latch*, or *spring bolt*, *d* by pressing against the lateral horn at its back end; this will cause the projecting portion of the bolt *e*, which fits into a plate fixed to the

door frame, or lining, to be drawn into the lock, and the door can be pushed or pulled open. If the spindle is rotated in the opposite direction, the knob *f* of the follower will lift up the arm *g* of the crank, which is pivoted at *h*, compelling the lower arm of the crank, which is attached to the bolt at *i*, to move back, drawing the bolt as before. In short, whichever way the handle is turned the bolt will be drawn back. The normal position for the bolt is, as shown in the illustration, with the part *e* projecting from the end plate of the lock ; this is maintained by the spring *k*, which presses down on the arm *g* of the crank and thus keeps the lower arm forwards, unless, of course, the handle is turned or the end *e* of the bolt is pressed in, as will happen when the door slams or is pushed to. When the door is pushed to, the curved side of the bolt *e* coming in contact with the striking plate is pressed in, but when the door is shut against the stop or rabbet in the lining, the bolt springs forwards into an opening in the striking plate and cannot be drawn back until the handle is turned.

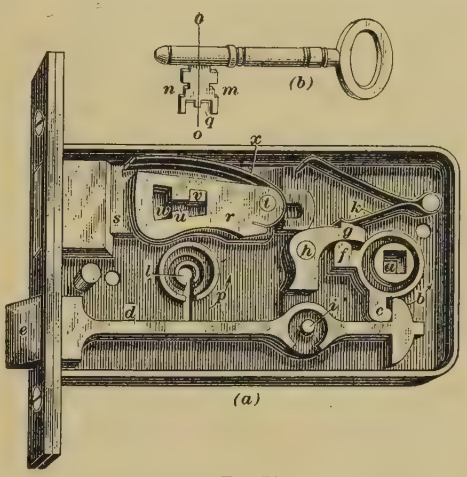


FIG. 54

65. The mechanism for locking the door is confined to the part of the lock shown in the upper left-hand part of the illustration. At *l* is the opening for the key, generally known as the keyhole, and the projecting ridges arranged in concentric circles round the circular part of the hole, where the shank of the key passes through, are known as the *wards ;* they are such that when the key, shown at (*b*), is inserted, the notches in the side *m* of the key must fit over the section of the wards. If

they do not, the key will not turn in the lock, so these wards are a safeguard against the lock being operated by a wrong key. If the key were inserted from the side of the lock shown in the illustration it is clear that the side *n* of the key would come in contact with the wards, and so the notches at *n* must be the same as at *m*. With any lock to be operated from either side by the same key, the working part at the end of the key must be symmetrical about some line such as *o o*. Exactly similar wards should be formed on each side plate of the lock.

When the right key is inserted in the lock and twisted in the direction indicated by the arrow *p*, the end of the key peak *q* will come in contact with the under side of the *lock-levers r* and the *lock-bolt s ;* the lock-bolt is also called a dead bolt, because it is not controlled by a spring like the latch or spring bolt, but remains in or out as the key leaves it. The levers are plates pivoted at *t*. They are not exactly of the same form, but are such that, when lifted to their various heights by that part of the key at *q*, they afford a clear passage at *u* for the projecting nib *v* on the lock-bolt to pass forwards into the space *w* ; they then drop and hold the nib *v* in that position until the operation is reversed by turning the key in the opposite direction. The part *q* of the key, in addition to raising these levers, pushes the lock-bolt backwards or forwards when it has raised the levers to allow the nib *v* to pass through at *u*. It will readily be seen that the greater the number of levers, the less chance there is of the lock being operated by the wrong key. Except when held up by the key, the levers are kept down by the springs *x*.

66. The mechanism of various locks will be found to vary in small details, but the general principles are practically the same in all. In a good lock, the mechanism should work with a minimum of friction ; the axis of the handles at *a*, Fig. 54, should be at a sufficient distance from the edge of the door to prevent the hand from being knocked against the door frame or lining ; the working parts of the lock should be of some very hard metal, such as gunmetal, bronze, or hard steel ; the spring or springs should be fairly strong, otherwise the latch may remain back and not be forced out by the spring.

The spring bolt *e* must have its play toward the striking plate when the door is open, hence it will be the opposite way round in a door which opens the other way. Mortise locks are made of such a design that the bolt may be put in either way round; such a lock is said to have a *reversible bolt.* Sometimes a *roller bolt* is employed, in which a small roller replaces the bevel, as shown in Fig. 56. This allows the door to close with less friction of the bolt on the striking plate. The size of a lock is specified by giving its length from the front plate to the back, thus, 4 inches, $4\frac{1}{2}$ inches, 5 inches, etc. The number of levers is also stated.

67. Rim Locks.—The **rim lock,** as illustrated in Fig. 55, is generally used for buildings of the cheapest class, such as model dwellings and small houses. As cheapness is the controlling factor in such goods, especially the goods made for speculative building purposes, the quality diminishes with the price. For cheap work, rim locks are used on account of their low cost and because they are easily applied. They are usually supplied with handles and escutcheons complete. Rim locks are made in various sizes and either square or rectangular in shape, the long dimension being placed either horizontal or upright. They may also be obtained with either iron or brass bolts, and are furnished with iron or nickel-plated keys. The cheapest qualities of rim locks are made with two bolts and one lever, while the better qualities have from one to three levers.

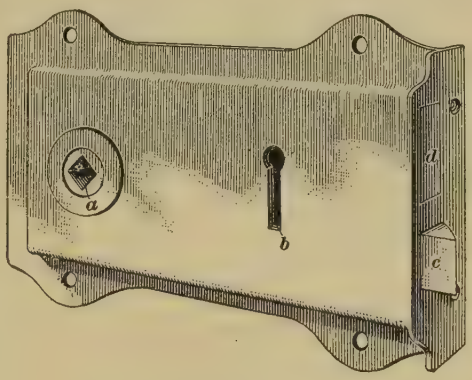


FIG. 55

Iron rim locks are generally constructed with stamped iron cases, and in selecting them a careful inspection should be made of the internal mechanism and general workmanship; a great

many rim locks are sold which are almost useless. Sometimes a rim lock may be used having a case to which some form of ornament has been applied to enhance its appearance and render it of decorative value. At *a* is shown the hole for the spindle, at *b* the keyhole, at *c* the spring bolt, and at *d* the lock-bolt.

68. Mortise Locks.—In dwellings of the better class, the best types of rim locks are used for doors in attics and basements, and for closet doors, but for all other doors, **mortise locks** are used. These locks are provided with lock fronts of cast or wrought bronze or brass, are made with from one to four levers, and have drop-forge steel cases. The locks are constructed with easy springs, which allow the latch bolt to retreat within the case on one light spring when the door is closed.

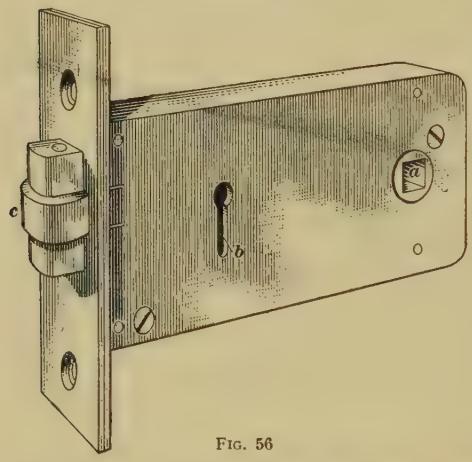


FIG. 56

The external appearance of an ordinary mortise lock is shown in Fig. 56, but, when fixed, only the front plate of the lock is visible on the edge of the door. At *a* is shown the opening for the spindle of the handle, at *b* the keyhole, and at *c* the combined latch and lock-bolt. The handles, or knobs, are not supplied with locks of this kind, but are selected according to taste from one of the patterns described later.

69. In Fig. 57 is shown a sketch of the stile of a door with a mortise lock fixed, showing how the lock-rail is worked with four small tenons and the mortise lock is fitted into the part of the stile and rail between them without interfering with the tenons. A lock of this kind would probably be 6 inches long, $2\frac{3}{4}$ inches in depth, and $\frac{5}{8}$ inch in thickness; the front plate *a* on the edge of the door is about $4\frac{1}{2}$ or 5 inches by 1 inch.

70. Latch Locks.—As a rule, latch locks are used on the entrance doors of town houses. They are operated from the inside by means of a handle or knob, but from the outside only by means of a key. The advantage of using them is that only those possessing the proper key can gain admittance to the house unless the door is opened from within. These locks may be worked on the same principles as the lever contrivances of ordinary locks, but with the addition of a spring to keep the bolt forwards. They usually have also a catch, worked by a small knob on the inside, which will hold the locking-bolt out of action, or will lock the bolt forwards so that the lock cannot be operated from without even by the right key. These locks are usually made in the form of rim locks. To avoid having long and cumbersome keys, various devices are used, such as inserting the lock-levers well into the door and having connections within the lock to the bolt-drawing mechanism on the inner face of the door, or using a mortise lock and a recessed escutcheon on the outside.

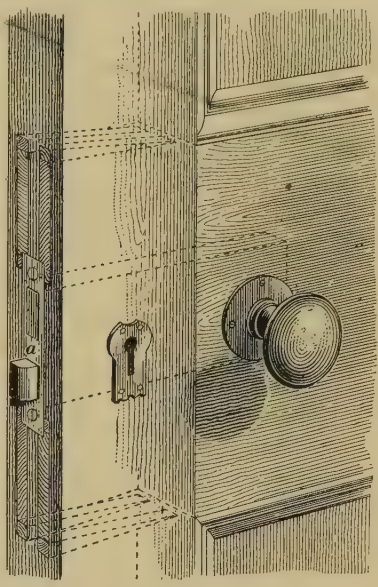


FIG. 57

71. Yale Lock.—A latch lock recently introduced in Great Britain is the cylindrical type shown in Fig. 58. This lock is generally known as the **Yale lock,** but is made under other names. In view (*a*) is shown a vertical section of the lock at right angles to the face of the door, while in (*b*) is shown the outside elevation of the lock. The key is inserted in the corrugated slot shown in (*b*), so that unless it is corrugated in exactly the same manner as the slot, it will not enter; this feature in itself provides considerable security against the lock being operated by any but

the right key. In (*a*) the key is shown in position to open the lock. In addition to the longitudinal corrugations, the key has irregular serrations on its edge, the functions of which are to lift the pins *a*. Each of these pins is in two pieces, which are pressed down by a spring, as shown. Until each pin is lifted to exactly the right height, to make the joint between the two parts of the pin exactly aline with the joint *b* between the inner and outer cylinders, the inner cylinder cannot revolve and the lock cannot be operated. When the key is not in the lock, the springs press the pins down, so that the joints between their upper and lower parts do not aline with the joints between the cylinders and the inner cylinder cannot be rotated. The great advantage of this type of lock is the almost infinite variety

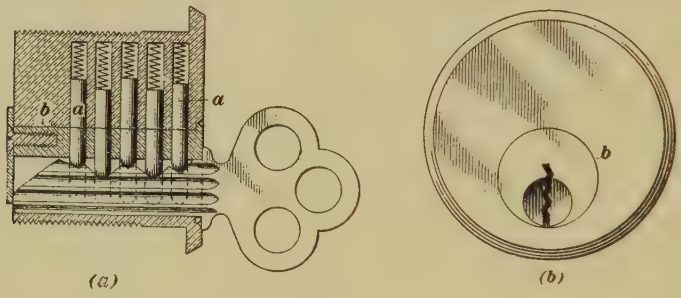


FIG. 58

that can be obtained, so that no lock can be operated by any but its own key. Many forms of corrugations are possible for the key slot, and the joints between the upper and lower parts of the pins can be varied almost without limit. Another advantage is the very small and convenient key, which can easily be carried in the pocket.

72. Drawback Locks.—Locks operated by drawing back the handle knob instead of turning the handle are known as **drawback locks.** A powerful spring keeps the bolt forwards unless the knob is drawn back ; a small catch at the back of the lock will hold the bolt back if required. Entrance-door latches are sometimes constructed on this principle, in which case they are operated from without by a key in the same manner as latch locks.

73. Dead Locks.—Locks that have only a dead bolt operated by a key are known as **dead locks**; they have no spring bolt or handle mechanism. They are frequently used on doors of cellars, cupboards, cycle houses, and in similar instances, and are of the rim class. A lock having a hardwood case, generally oak, known as a *stock lock*, is sometimes used on garden or outside cellar doors.

74. Padlocks.—A lock that is not rigidly attached either to the door or frame, but is generally affixed to a staple and hasp arrangement or a chain, is termed a **padlock.** It is extensively used for factories, stables, and other buildings of this character; thus some care should be taken in its selection. Padlocks are made in a great variety of sizes, styles, and qualities, and retail at prices ranging from a few pence to half a guinea. Where these locks are exposed to moisture or to the weather, they should be of bronze or of brass, with all the interior construction of the same material. If required for great security, that is, for places where they are likely to be subjected to violence, they should be very heavy, and preferably provided with steel shackles. Padlocks are as a rule constructed on the same principle as the lever dead-bolt arrangements, but they may also be had on the cylindrical plug or Yale principle. Padlocks do not afford any great security, as anyone wishing to break open a door secured by a padlock can file or saw through the curved arm or shackle, which passes through the staple eye or other fixture, and thus avoid tampering with the lock mechanism.

75. Sliding-Door Locks.—Sliding doors are often secured with a hasp and staple and padlock, but a better form of fastening is the **hook-bolt lock,** or latch, shown in Fig. 59. In (*a*) is shown the lock with the hook bolt *a*; in (*b*) is shown the striking plate. The latch *a* is fitted with a spring, so that when the door is closed the splayed under side of the bolt

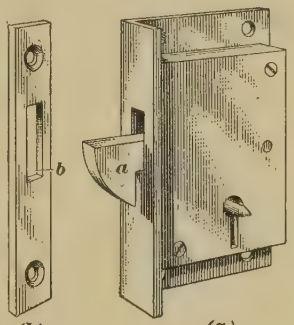


FIG. 59

comes in contact with the lower part of the opening *b* in the striking plate and is lifted until it passes through the opening, when the bolt is pressed down and the door is latched. In the lock shown, a key must be used to raise the bolt and open the door, although a handle might be provided to perform the same function.

76. Water-Closet Coin-Freed Locks.—In public conveniences and places where a charge is made for the use of a water-closet, **coin-freed locks** are generally used. When the word *vacant* is displayed on the indicator *a*, Fig. 60, the closet is available for use, and the door may be opened by inserting a penny in the slot *b* and turning or drawing back the knob *c*. An indicating bolt on the inside changes the indicator plate on the outside to *engaged*. When the bolt is drawn to open the door, the indicator is changed back to vacant. Different locks vary in detail from the type shown; for instance, some will work with the insertion of two halfpennies instead of one penny, while in some the indicator changes automatically to engaged as the door is opened and latches itself as the door is shut, rendering a bolt unnecessary. A handle on the inside allows the door to be opened again and changes the indicator. A keyhole *d* on the outside should always be provided for the attendant to open the door if necessary. The keyhole *e* is for the insertion of a key by which the front of the lock is opened to remove the money at intervals.

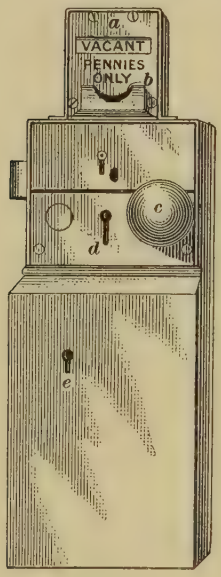


FIG. 60

77. Master-Key Locks.—The type of lock known as the **master-key lock** is generally used for public or office buildings, hotels, and occasionally in the better class of residence work. In the lever type, the levers are so arranged that each lock can be operated only by its particular key, the keys for all rooms being different and non-changeable. All the locks, however, can be operated by a key made for the purpose, termed a **master key.**

Such locks may be obtained either in the cheaper kind, with one lever and about 100 changes, or in the most intricate styles of hotel locks, with four levers and about 500 changes in one set, and all operated by one master key. Another advantage of this arrangement is that the loss of a key will not be attended by any great inconvenience, as the lock can be operated by the master key.

Owners or officials of large office buildings and industrial works now avail themselves of the master-key system. They are able to obtain mortise locks, rim locks, and padlocks arranged to operate with a master key, in one series. In first-class residences also this system is adopted. Such a system of locking is easily recognized as convenient, especially where subordinates are held responsible for certain rooms or departments to which they, individually, have access, as all of the rooms or departments may be entered by the manager or superintendent by the aid of the master key.

78. A series of master-key locks may also be *submaster-keyed* by dividing it into subordinate groups. In such a case, each group is operated by a master key of its own, and all the subordinate groups are controlled by a grand master key. For example, a six-story office building could be furnished throughout with locks having non-changeable keys ; the doors of each floor could be operated separately by a master key ; and the doors of the entire building could be operated by a grand master key. The convenience of such a system is readily apparent in large buildings where each head clerk or assistant is responsible for a certain floor, and where the manager, or owner, has control of all the locks by means of the grand master key.

79. Lever Type of Master-Key Lock.—In Fig. 61 is shown a form of lever master-key lock which may be operated by the ordinary change key shown in (*a*), which is inserted in the keyhole *a*. One way of making several locks of this kind, each to work with its own key and yet to be worked also by one master key, is to form the levers of all the locks alike and vary the wards. The master key is then made, as in (*b*), with the part of the key which should fit over the wards missing. As

all the keys have the parts at *b* alike, to operate the arrangement of levers common to all the locks of the set, the master key would open the door. The disadvantage of this arrangement is that by filing away the parts *e* of any key of the system, it becomes a master key and so will operate any of the locks. In the lock shown, however, a better arrangement has been introduced. That part of the levers *d* which comes in contact with the ordinary key (*a*) when inserted into the lock at *a* is different for every lock of the system; therefore, no key can,

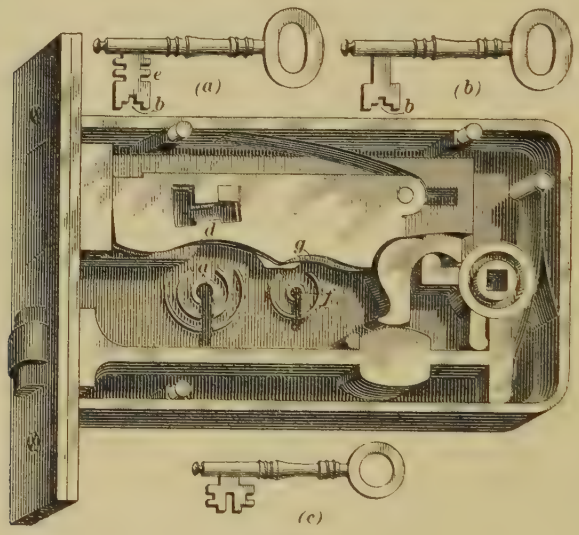


Fig. 61

by any process, be made capable of working one of the other locks. The master key is made smaller, as in (*c*), and is inserted into another hole *f*, thus coming in contact with the lock-levers at *g*, where they are alike in all the locks. Locks are still made, however, with only one keyhole and are grouped into classes, each lock in which has its key, which is not applicable to any other lock of the class, and yet every lock of the class may be operated by the master key. These classes are then combined into a larger class that may be operated by one grand master key. The detailed arrangement of a system of this kind

is too complicated to be devised by any but a thoroughly competent locksmith continually occupied in such work ; and when such a system is required, only firms of good repute should be trusted with the work.

80. Yale Master-Key Lock.—A master-key lock of the Yale cylindrical principle may be made in two systems : the *regular* and the *concentric*. In the **regular system,** one regular cylinder is controlled by the change and master keys, the pin tumblers being cut in two places, so that the change key brings one set of the abutting planes of the pins in alinement with the surface of the cylindrical plug. This plug is arranged so that a separate key is required to operate each lock ; the other line of cleavage through the blocks is the same with all locks throughout the series, so that they may be opened with the same key.

81. The **concentric cylindrical arrangement** of this type of lock is shown in Fig. 62 (*a*) and (*b*). Here, a larger cylinder *a*, known as the *master-ring*, or *larger, plug*, encircles the key

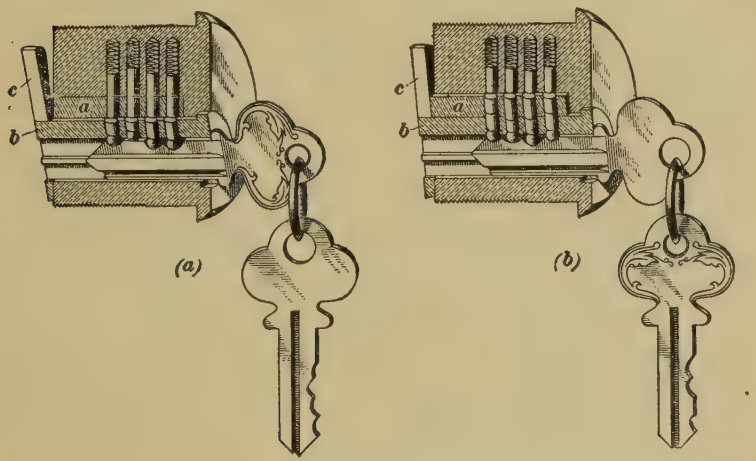


Fig. 62

plug. When the change key is inserted in the key plug *b*, the lower series of breaks in the pins comes into alinement with the outer edge of the plug, as shown in (*a*), and allows it to revolve within the master ring ; the cam *c* on the inner side then actuates

the lock. When the master key is inserted, the upper series of breaks comes into alinement with the outer edge of the master ring, as shown in (*b*), and allows the plug and the ring to rotate together with the turning of the key. This produces the same result as that caused by the operation of the change key.

82. Hotel and Office Locks.—The term *corridor door* designates the entrance from a corridor or a hall to a bedroom or an office, while *communicating doors* are those between adjoining rooms. Frequently, these doors are double, and are then known as *double doors*, while the term *closet doors* is self-explanatory. Each of these doors requires a *knob lock*, that is, a lock having the latch bolt operated by the knob and the dead bolt operated by a key. Sometimes, in the case of locks on closet doors, the dead bolt is omitted, and a barrel, or indicating, bolt substituted. While all the locks thus far described may be used in hotels, and most of them in office buildings, technically speaking, an *hotel lock* is a master-keyed knob lock for doors from the corridor to bedrooms. For these, a good-quality lever lock with round, substantial keys is desirable, because the keys are liable to hard usage, and should not be convenient to carry in the pocket. Hotel locks vary widely in arrangement, as well as in size, quality, and price. The kind of action, or mechanism, to be adopted in an hotel lock is frequently determined by the preference and experience of the hotel manager, and he should be consulted beforehand; but the position and use of each door should be considered in the selection of the locks for this character of building. The subject of ironmongery for an hotel is one that requires the most careful consideration of the architect.

The grouping of locks in an hotel should be studied. Usually, the best plan in large hotels is to group all the locks on each floor under one master key and to provide a different master key for each floor, care being taken to limit the issue of master keys to the smallest possible number of responsible persons. A grand master key that will open all the locks on every floor is also provided. The usual lock or latch used in hotels is a one-bolt latch, operated by the key on the outside, and is drawn by a knob on the inside. This is so arranged that the grand master

key can lock any of the rooms against the visitor should occasion arise.

83. Considerable confusion is frequently created by hotel guests taking with them on departure the keys to their rooms. Formerly, hotel managers sought to prevent this practice by using large **key tags** of iron or brass, generally serrated on the edges and made so cumbersome as practically to preclude their being carried in the pocket. Subsequently, large tags made of red fibre became popular. The usual form of these large tags, whether of brass or fibre, is illustrated in Fig. 63.

FIG. 63

84. Office locks are grouped in the same manner as hotel locks for operation with the master key. In other respects, however, they differ considerably, for an hotel lock must secure the door both when the room is occupied and when it is not, but an office lock is used chiefly to secure the room when it is not occupied. In consequence of this, certain differences in action are employed. All office locks have a latch bolt that is operated by the knob from both sides and yet permits free ingress and egress. Various methods, however, are used to lock the door against ingress, except by means of a key. Sometimes this is accomplished by means of a separate dead bolt operated by a master key from either side ; in other cases it is accomplished by a latch bolt only, by providing the latter with a stop-work like a front-door lock. By this arrangement, the outer knob may be stopped so that the latch bolt cannot be operated from the exterior except by the key ; and, again, the latch bolt may be dead-locked from the outside by the key. The choice of these arrangements is a matter of personal preference.

85. Special Locks.—So many special locks are in use that it is impossible to deal with them fully. These should be obtained from a reliable maker and the working principle should be mechanically sound and not easily deranged. In many cases expert advice is necessary, especially in view of the improvements that may be introduced from time to time. This is

especially necessary in the case of safe and strong-room locks for banks or large companies that keep considerable valuable property under lock and key. These locks are of very complicated mechanism, containing the most ingenious devices for preventing illicit access to the guarded property. Among them is the *time lock*, which is actuated by clockwork and is arranged to prevent the unlocking of the door except during certain hours. *Bolt-motor* contrivances operate automatically when released by the time lock and have the advantage of being entirely on the inside of the door without spindle or other connection with the outside; they are thus inaccessible to burglars. *Dial* or *combination locks* and similar fastenings are designed to resist burglary or fire. Other locks that must be carefully considered by experts are those used in prisons and asylums. These must be constructed so as to resist any tampering they may be subjected to by persons devoid of reason or possessing peculiar ingenuity. Some of these locking devices must be built into the structural parts of the building, and so should be considered and selected before the plans are too far advanced.

86. Care and Maintenance of Locks.—Locks, like other pieces of mechanism, need reasonable care and attention to keep them in the best condition. As they contain moving parts, they are subjected to frictional wear and need occasional lubrication. Most of the friction, and consequently the wear, occurs in the bevelled latch bolt, which may readily be lubricated. If the latch bolt is troublesome, its face and back should be cleaned with a cloth moistened with naphtha or kerosene to remove any dirt. These surfaces should then be wiped with another cloth saturated with machine oil or, better, with vaseline. Any person can perform this simple work, and if it is done once or twice a year, it will keep the bolts in such condition that each door will close easily and quietly at all times. Another cause of trouble is the tendency of the old-fashioned knob screw to become loose, thus allowing the knob to pull from the spindle. Where such spindles are used, they should be inspected occasionally and any loose screws tightened. The best results will be obtained by having all locks and furniture inspected by an expert about once a year.

87. Hand and Bevel of Doors.—Many locks and butts used at the present time are made *reversible*, that is, they can be used for either right- or left-hand doors. Others are not, and must therefore be specified as *right hand* or *left hand*. In this latter class are included the majority of rim locks and loose-joint and rising butts, the operation of which is different on one side from that on the other. A **reversible lock** is one having a bevelled latch bolt that can be turned over, or reversed at will, to give

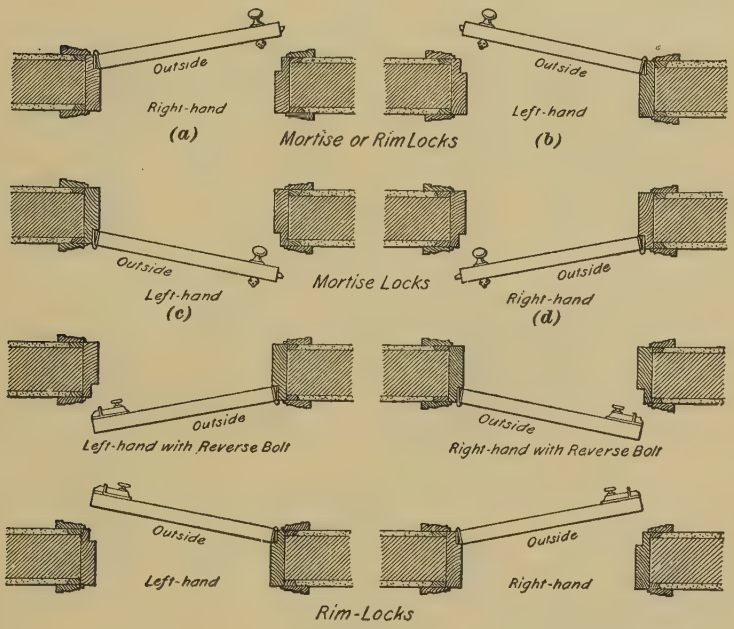


FIG. 64

its bevel face the opposite direction. This is usually accomplished by removing the cap of the lock and turning over the latch bolt, and can be done only with mortise locks.

In order that ironmongery may be ordered intelligently, the *hand* of the door should be given where the fittings are not interchangeable or reversible. Rules to determine the hand of doors and windows have been made, so that information may be furnished to manufacturers on a uniform basis. See Fig. 64.

1. The **hand** of a door is always determined from the outside.

2. A door opening *inwards*, and having a mortise or rim lock fixed on the right, is a *right-hand* door; if fixed on the left, it is a *left-hand* door.

3. A door opening *outwards*, and having a mortise lock fixed on the right, is a *left-hand* door; if fixed on the left, it is a *right-hand* door.

4. A door opening *outwards*, and having a rim lock, is designated in accordance with rule 2.

It is necessary to specify a reverse bolt only in ordering a rim lock. In the case of a mortise lock, the bolt is reversible, so that, as far as a mortise lock is concerned, that shown in Fig. 64 (*a*) is the same as that shown in (*d*); and that shown in (*b*) is the same as that shown in (*c*). This accounts for the different description given for doors opening out, according as rim or mortise locks are used. When specifying the hand of fasteners for casement windows, the same rule applies; but it does not matter whether they open in or out.

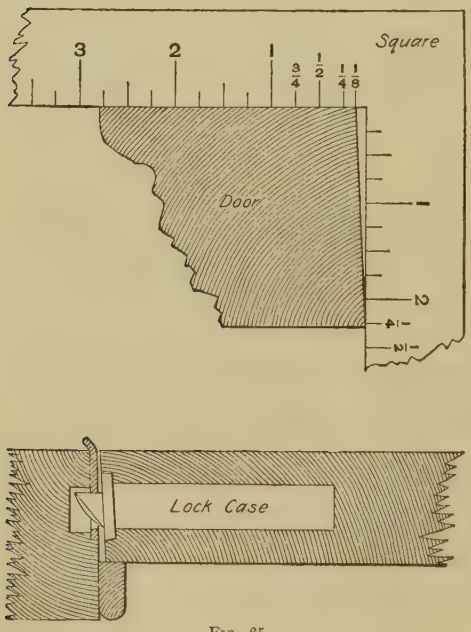


Fig. 65

88. A door is **bevelled** when its edge is not at right angles with its surface, in which case the front of a mortise lock must be bevelled to correspond. This bevel is expressed by stating the thickness of door and the distance that one edge drops behind the other. The standard bevel is $\frac{1}{8}$ inch in $2\frac{1}{4}$ inches,

as shown in Fig. 65. Mortise locks used with double doors having either rabbeted or astragal joints, must have fronts of corresponding sectional form. To avoid the extra cost of special patterns, the rabbet or step on the edges of such doors should conform to established lock standards, usually $\frac{1}{2}$ to $\frac{5}{8}$ inch.

89. The proper bevel of a door, if any is needed, is determined by the size of butt and the width of the door, as shown in Fig. 66. The inner corner of the door travels on an arc having its centre at the centre of the pin of the butt, and must have a clearance to swing free of the jamb casing. This may be obtained by bevelling the edge of the door, or, if its edge is left square, by leaving sufficient clearance between the door and its jamb. As a rule, however, a square edge may be used without resorting to an unduly open joint, thus permitting the use of locks with regular front, that is, not bevelled.

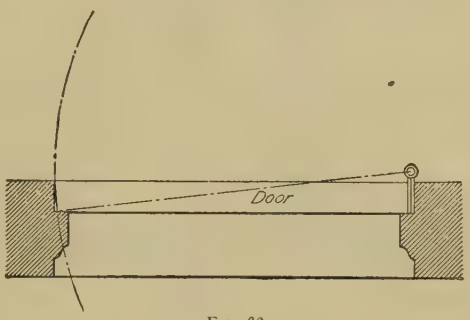


Fig. 66

LATCHES

90. Types of Latches.—In Fig. 67 is shown the simplest form of latch. A catch *a* is fastened to the door frame, and the lever, pivoted at *b*, is fastened to the door. To open the door the lever is lifted by the knob or handle *c* until its end is raised above the catch *a*, when the door may be opened. The bevelled upper end of the catch causes the lever, when the door is closed, to rise and ultimately fall into its notch without being specially lifted. This latch

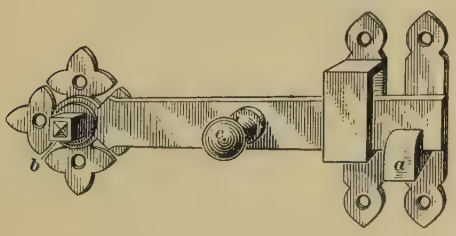


Fig. 67

can be operated only from one side of the door. A **thumb latch,** shown in Fig. 68, allows the door to be opened from the other side. The arm *a* passes through the door just under the lever of the latch. Then, when the thumb depresses the plate *b*, the arm *a* rises and lifts the latch. This latch is also known as a *Norfolk* or *Suffolk latch.* A latch of this external form is used in conjunction with a mortise latch, as shown in Fig. 69, which shows a stub to lock the latch on the inside at *a*.

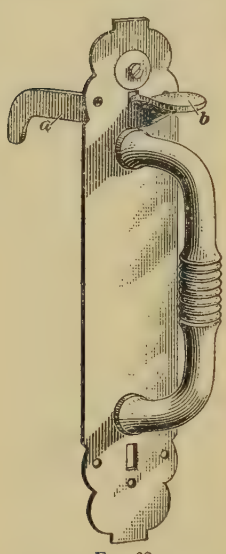


Fig. 68

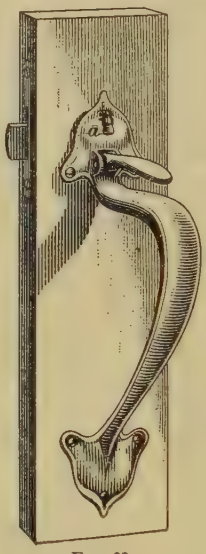


Fig. 69

91. Gate Latches. The form of latch generally used on a gate is shown in Fig. 70 (*a*). For a gate that will open only one way, the striking plate takes the form shown in (*b*). The latch *a*, view (*a*), strikes the curved surface at *a*, view (*b*), and is raised until it falls into its slot *b* and fastens the gate. For a gate that will swing both ways, the striking plate, as shown in (*c*), should have a splayed upper surface on each side;

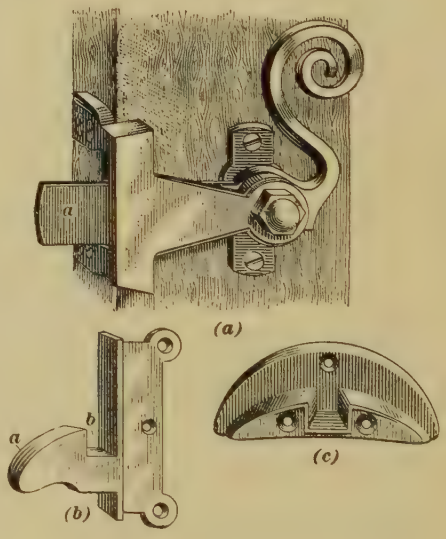


Fig. 70

this should be fixed on the face of the post toward the other post. The plate shown in (*b*) should be fixed so that the catch will project on the side toward which the gate is opened.

DOOR BOLTS

92. Rim Bolts.—A large variety of **door bolts** is now on the market. These bolts are made in all sizes, in wrought iron, cast iron, brass, and bronze, and may be procured in any finish desired. In Fig. 71 are shown several types of **rim bolts,** that is, bolts applied on the surfaces of doors. In (*a*) is shown an ordinary round *barrel bolt;* in (*b*) a *tower bolt,* which differs only from a barrel bolt in that the bolt does not move in a continuous socket, but passes through two or more guide clips *a* ; in (*c*) is shown a short form of the same kind of bolt. A *necked bolt* is shown in (*d*), and in (*e*)

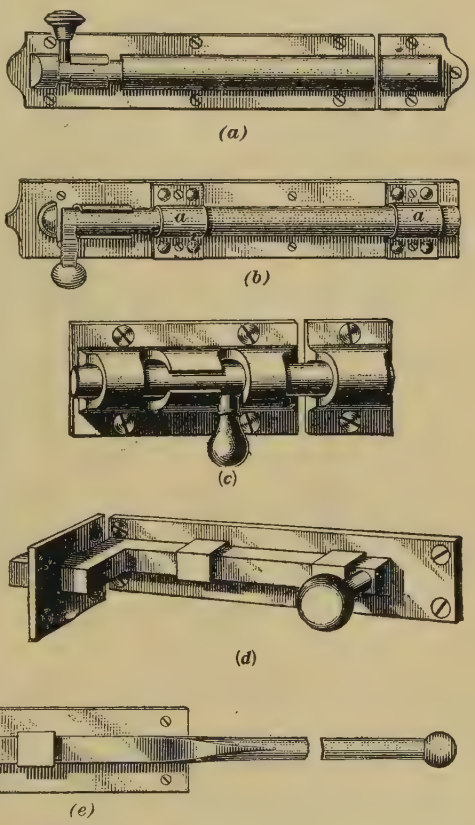


Fig. 71

a form of tower bolt, known as a *monkey-tail bolt,* for use on a high door where a bolt of ordinary length would be out of reach.

93. Flush Bolts.—In Fig. 72 are shown three forms of **flush bolts,** which are let into the surface of the door and are flush therewith. The bolt shown in (*a*) is operated by pushing the small slide *a* with the thumbnail. The bolt in (*b*) is operated by turning over the lever; the lever is flush for both positions of the bolt. A bolt of this kind fixed on the rebate of folding doors

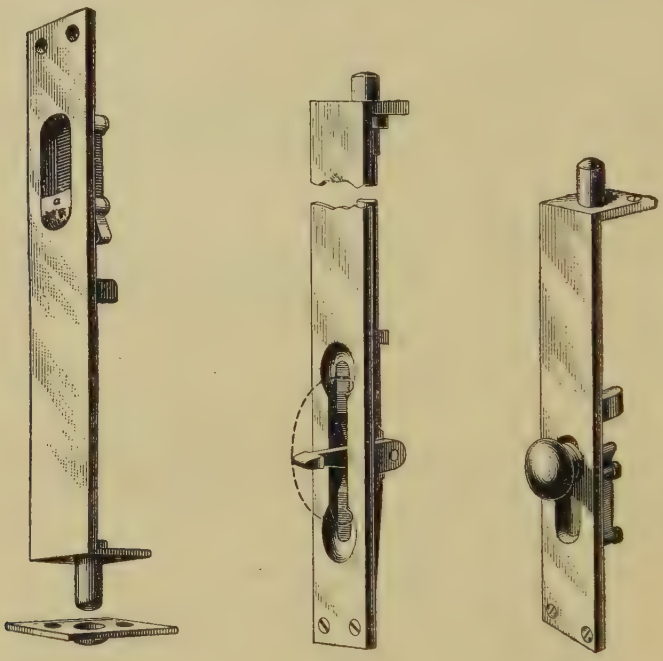


FIG. 72

cannot be drawn until the other leaf is open. In (*c*) is shown a flush bolt fitted with a projecting knob.

94. Mortise Bolts.—In Fig. 73 a **mortise bolt** is shown. The bolts *a*, *b* are entirely embedded in the stile of the door and are operated by turning the handle. The bolts fit into sockets *c*, *d* in the head and sill of the door. As shown in the illustration, the bolts are out when the door is shut; depressing the lever

handle draws them both in. A bolt of this kind may be used on the first closing leaf of folding doors; on the second, a mortise dead bolt may be fixed, which, when locked into the first leaf, secures the doors and makes a very safe lock. Or a mortise dead bolt may be combined in one lock with the mechanism shown, in which case it will be fixed on the second closing leaf.

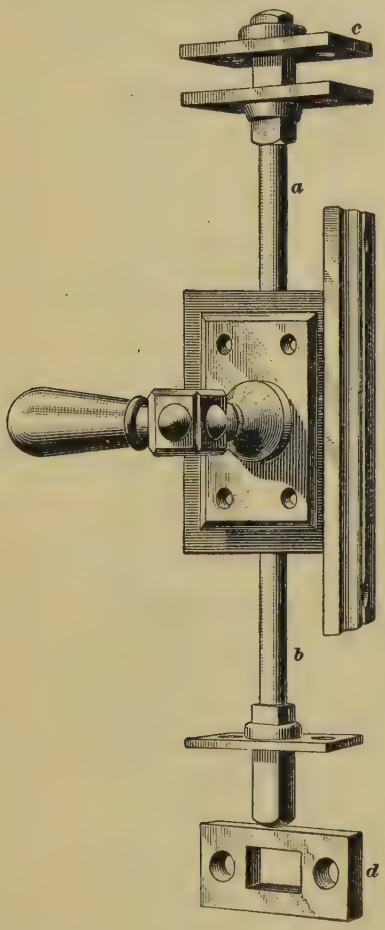


FIG. 73

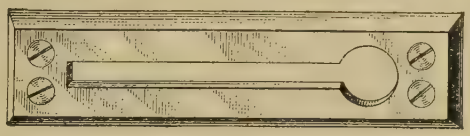
95. Panic Bolts.—In Fig. 74 is shown the general appearance of panic bolts as fitted to swing doors. They are so constructed that the door is quite secure against anyone attempting to enter from without; but in case of anyone wishing to go out the bolts are immediately drawn and the door opened on pressure being applied to the horizontal bar. At *a* is shown the position of the bar when the door is locked; the bolt ends *c*, *d* are then in the sockets in the sill and head. When the bar is pressed into the position shown at *b*, the bolts are drawn and the door will swing open. On some makes of these bolts, a catch is fitted which holds the apparatus out of action if required, so that the doors become ordinary swing doors. The bolts may be operated from without by a key. The advantage of these bolts on the exit doors of all places where large numbers of persons assemble is obvious. A similar device for single doors consists of

a horizontal bar only, which operates a mortise latch. This arrangement is known as a *panic latch;* it may be applied to one leaf of double doors if a panic bolt is applied to the other.

Fig. 74

96. Door Chains.—The type of chain fastener shown in Fig. 75 is generally used on exterior residence doors. This device allows the occupants to open the door partly without permitting entrance. It consists of a heavy chain, one end of which is attached to a plate, which in turn is fastened to the jamb with screws. The other end of the chain carries a ball or a hook that

may be inserted in the slot of the long plate, which is attached to the door. By this means, the door may be opened only slightly, until the ball of the chain is released from the slot.



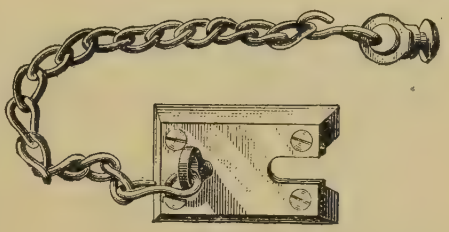
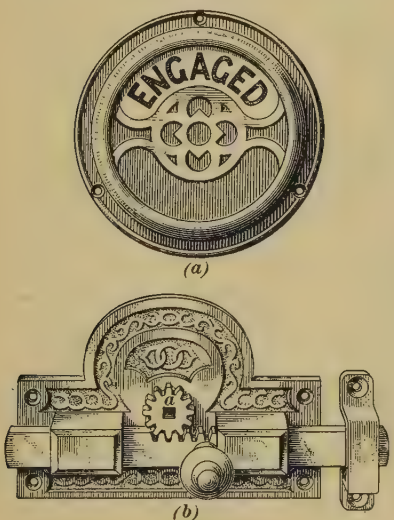


Fig. 75

97. Water-Closet Indicating Bolt.—The construction of water-closets in public buildings has necessitated special fittings to meet the various conditions of convenience, simplicity, and hard usage. In ordinary work the doors of water-closet compartments are secured with a barrel bolt, while in the better class of work, as in hotels and public places of this character, rim or mortise latches or, better, indicating bolts are used. An example of an **indicating bolt** is shown in Fig. 76. In (*a*) is shown the part fixed on the outside of the door, which displays the word *engaged* when the bolt, shown in (*b*), on the inside of the door is in the position to keep the door shut. When the bolt inside is drawn back, it rotates the cogged wheel at *a*, which turns the plate in the indicator and brings the word *vacant* into view instead of the word *engaged*. Indicating latches may also be obtained, either rim or mortise, to replace the bolt, but with a similar indicator.



(*a*)

(*b*)

Fig. 76

98. Hasp and Staple and Locking-Bar.—The usual locking arrangements for coach-house, stable, and often warehouse doors

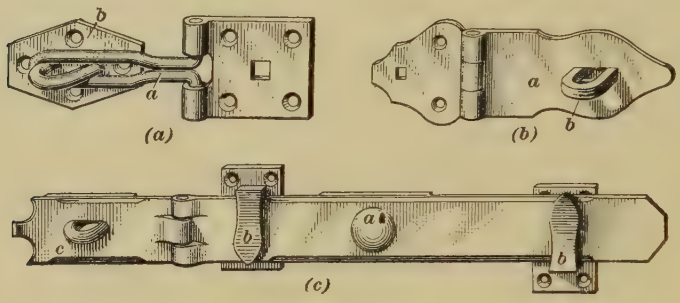


Fig. 77

are shown in Fig. 77. In (*a*) and (*b*) are shown two forms of **hasp and staple**, *a* being the hasp and *b* the staple. This fastening is secured by a padlock, the shackle of which passes through the staple. In (*c*) is shown a swivel bar, with knuckle joint, hasp, and staple, known as a *locking-bar*, which is applied to folding doors. The bar is pivoted at *a* in one door, and, when closed, is held in the two clips *b*, one on each door, and padlocked by means of the hasp-and-staple arrangement *c*. In many of these bars the clip near the hasp and staple is omitted.

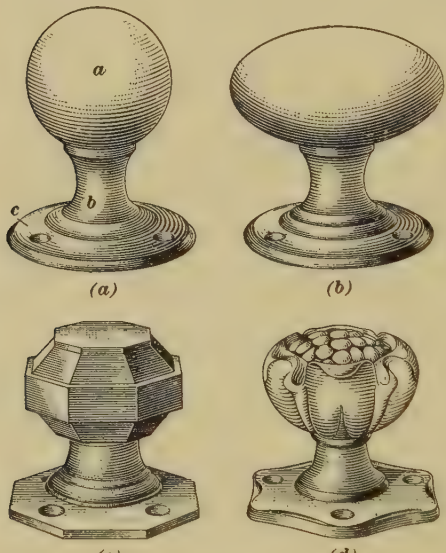


Fig. 78

One leaf of the doors must be secured inside by two bolts, one at the top and the other at the bottom, in addition to this locking-bar, which secures the doors only to one another.

LOCK FITTINGS

99. Forms and Materials of Knobs.—Door knobs are made in a variety of shapes and materials. In Fig. 78 are shown four types, which would be described, as to the shape, as (*a*) *round* or *spherical*, (*b*) *oval*, and (*c*) *octagonal*. That shown in (*d*) would have to be described as *fancy*. This last class may be extended indefinitely, and even the other classes may merge one into another. It is, however, a matter of no importance to divide door knobs into classes on the question of their form, but it is of some importance to take account of their various materials and methods of manufacture and the relative merits of each. In Fig. 78 (*a*), *a* is the knob, *b* the shank, and *c* the rose.

100. Cheap qualities of door knobs, such as are supplied with rim locks, are made of spun or stamped brass and the shank is sweated on. China knobs may also be had, either black or white, or white with flowers or other enrichments in colour. China knobs have the shank in one piece with the knob, but a brass rim would be fixed as a finish; the rose may be either china or metal. China knobs are, of course, more liable to breakage than metal, the rose especially so. Wooden knobs are sometimes used, especially in hospital work, but, if they have metal shanks, they must be very securely fastened on and not merely attached by means of glue or cement. Wooden roses tend to split along the grain. In Fig. 79 (*a*) a wooden knob is shown with a metal rose, at (*b*) a wooden knob with a wooden rose.

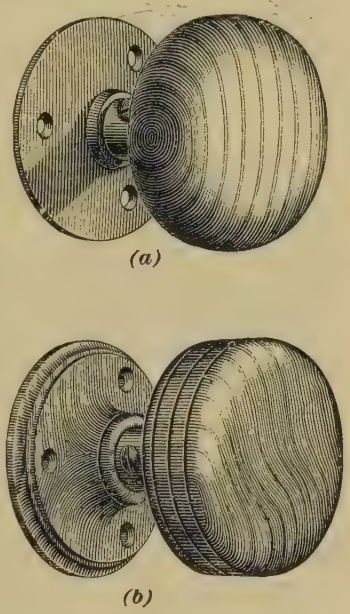


Fig. 79

101. The most expensive knobs made are those of cut glass with metal mountings. Several knobs of this kind are illustrated in Fig. 80. Cut-glass or crystal-glass knobs are very costly, the price depending on the style and the amount of cutting required and on the quality of glass used.

Knobs of bronze or brass are always used in buildings of the better class, and all ornamental knobs of the higher qualities are made of these materials. The best knobs are usually solid, that is, cast in one piece with the shank. They may be finished

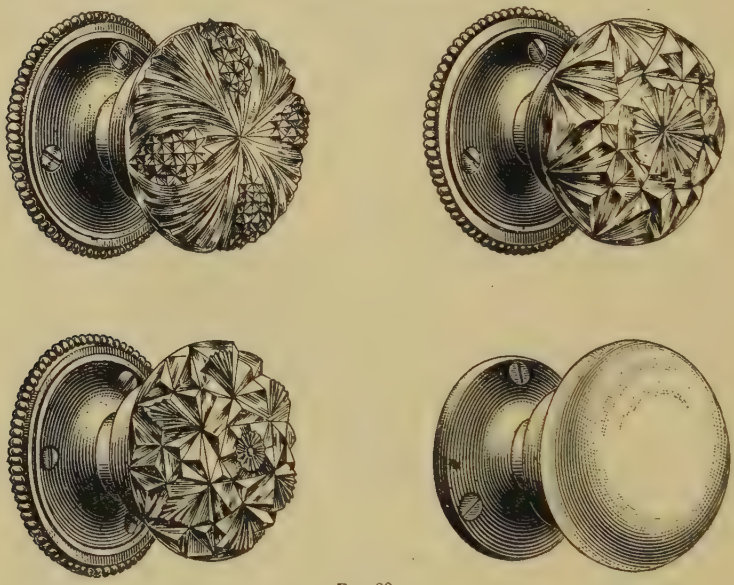


FIG. 80

as to colour and surface in any of the fancy finishes previously mentioned, to harmonize with other metal work in the room.

102. Lever, Drop, and T Handles.—The type of door handle known as a **lever handle** is illustrated in Fig. 81; the latch mechanism is operated by depressing the lever *a*.

Another form of handle is shown in Fig. 82, and is known as a **drop handle**; the handle is free to rotate about its fastening to the spindle in planes at right angles to the surface of the door. To operate the latch, the handle must be turned in a

plane parallel to the door surface so as to cause the spindle to rotate. An example of a **T handle** is given in Fig. 83. Except in form, it is similar to the knob handles. These three classes of handles are made in cast brass or bronze; the drop handles may possibly be of black cast iron. The exact form of the handle may vary almost infinitely according to the taste of the designer, and all the previously mentioned metal finishes may be applied.

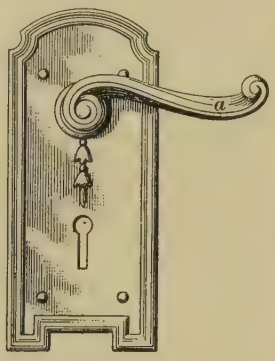


FIG. 81

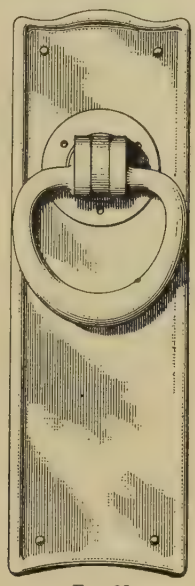


FIG. 82

103. Stable-Door Handles.—In Fig. 84 is shown a common form of flush handle for use on stable and coach-house doors. It may operate either a lever lock on the other side of the door, or a mortise or rim lock, or a lever latch.

104. Sliding-Door Handles.—A form of flush handle suitable for sliding doors is shown in Fig. 85. This handle is let into the edge of the door, and when not in use the part at *a* is practically flush with the plate *b*, which is screwed to the edge of the door. When it is to be used to pull the door, the little horn *c* is pulled forwards and the handle rotated about the pivot at *d* till the horn *c* comes down to the lower end of the plate, when the handle will be projecting beyond the edge of the door. Other forms of flush handles consist of such as may be pressed inwards and flush with the surface of the door.

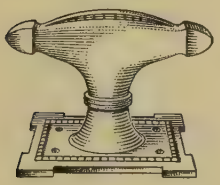


FIG. 83

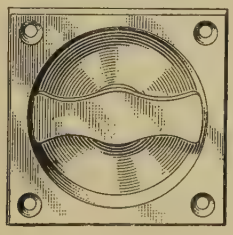


FIG. 84

The advantage of a handle placed on the edge of the door is that the pull is transmitted direct to the axis of the door. Ordinary grip handles, or even knobs, may be applied on the face of the door if desired, but more force is needed to move the door, as the pull is not axial. For light doors a flush handle in the side of the door may be used; such a handle is shown in Fig. 86

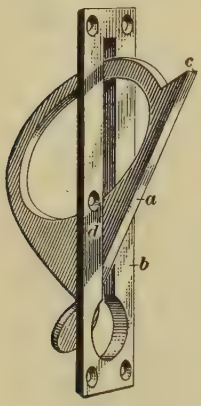


Fig. 85

Fig. 86

105. Fixing Knobs to Spindles. — At *b*, Fig. 87, is shown the bar which passes through a door lock; it is square in section and is known as a **spindle.** The standard size of spindle is $\frac{5}{16}$ inch. When rotated by means of the handle it operates the spring or latch bolt. Three of the best-known methods of fastening the knobs to a spindle are *Wilke's method*, *Mace's method*, and *Pitt's method.*

106. In **Wilke's method**, a small setscrew passes through the shank of the knob and fits into a sinking in the spindle, as shown in Fig. 87 at *a*. Several of these sinkings are formed on the spindle close to one another, so that the distance of the handles from each other may be adjusted according to the thickness of the door; however, it is practically impossible to do this accurately, so that the door handles are generally somewhat loose.

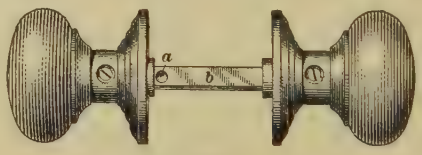


Fig. 87

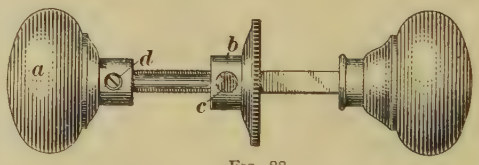


Fig. 88

107. **Mace's method** is illustrated in Fig. 88. It is an improvement on Wilke's in that the spindle is threaded and the knob screwed on, the spindle being made fast to the other knob.

When the knob *a* has been screwed up sufficiently far, the shank is within the part of the rose at *b* and the whole is close up against the surface of the door. A setscrew is then inserted through the hole *c* in the rose and *d* in the shank and driven into a slot in the spindle to prevent the handle from being screwed off ; the head of the screw is then flush with the surface of the shank, and the rose, which fits fairly closely over the shank, is turned round so that the screw head is covered.

108. In **Pitt's method,** the shank and rose are connected so that they cannot be separated, but so that the knob and shank may revolve independently of the rose. The handle is then put on over the spindle and the rose screwed to the door. This method forms a very good and satisfactory fixing. In Fig. 89 a handle fixed in this manner is shown. The spindle appears at *a*. The rose *c* fits over the shank of the knob *b*, and the washer *d* is screwed on to the shank and riveted to it so that the rose cannot come away from the knob, but the knob can revolve independently. The handle is put over the spindle and screwed to the door.

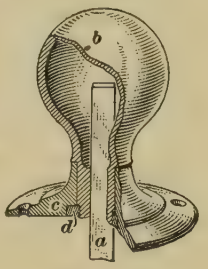


FIG. 89

DOOR FURNITURE

109. Escutcheons and Lock-Plates.—To avoid the unfinished appearance and the possibility of damage to the woodwork that

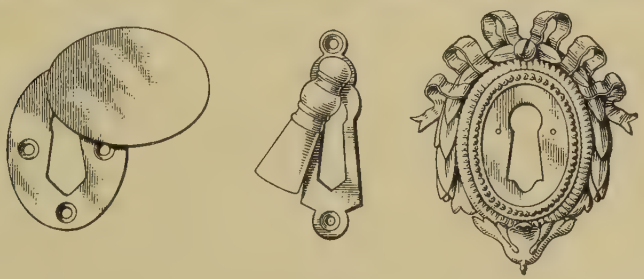


FIG. 90

would result from leaving the keyhole unprotected in doors where mortise locks are used, metal plates, known as **escutcheons,** are

fixed round the hole. They generally include a cover-plate to hang over the opening when the lock is not in use, and they may be quite plain or highly ornate, and are often designed to match the door knobs employed. Three examples are shown in Fig. 90.

Lock-plates are metal plates of the form shown in Fig. 91, the narrow part covering part of the closing stile of the door and the broad piece extending over part of the lock-rail. In the illustration, the handle and escutcheon are shown in their positions on the lock-plate.

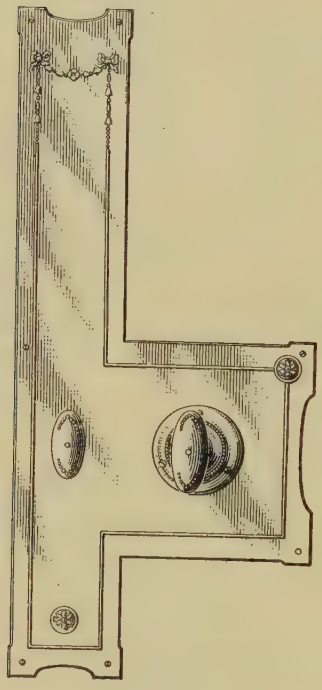


Fig. 91

110. Finger Plates.—On double-action or single-action doors, **finger plates** are used to protect the woodwork against soiling and wear from handling. These plates are made in various sizes, and are either plain or ornamented to harmonize with the other fittings. To obtain good results, finger plates should be as wide as the closing stile, where possible, and from 12 to 30 inches long, according to conditions and use. In doors where a lock-plate is not fixed, one finger plate is generally fixed on the closing stile above the lock, and in some cases another is fixed below. If used in connection with a dead lock, the plate should be cut or drilled, preferably near the bottom, to allow the key of the lock to pass through the plate. A plain type of metal finger plate is illustrated in Fig. 92 (*a*), while one of more ornamental design is shown at (*b*). They may also be made of hardwood or china and in a great number of designs; all kinds are merely attached to the woodwork by means of metal screws.

111. Kicking Plates.—A kicking plate is a modern device which is applied to the bottoms of doors to protect the woodwork from injury and wear, being used chiefly for swing doors and doors of public buildings. These plates are usually made of rolled sheet metal, and are sometimes ornamented to harmonize with other metal work of the door.

FIG. 92

Kicking plates should completely cover the bottom rail of the door, but if cost is the controlling factor, they may be cut down in height so that a margin of wood the same width as the stile shows above the plate. For instance, if the bottom rail is 12 inches in height and the stile is 5 inches wide, the kicking plate should be 7 inches high. In some cases the top of the plate is cut, not straight, but in flowing curves or other forms. In all cases,

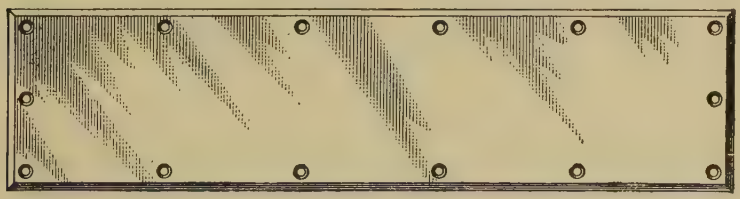


FIG. 93

kicking plates should extend the full width of the door, allowing

enough margin, when used on double-action doors, for the rounding of the edges. When used on single-action doors having rabbeted jambs, the rabbet of both jambs should be deducted from the length of the kicking plate. A typical kicking plate of plain pattern is shown in Fig. 93. Such plates are generally sold at a price per square foot.

112. Letter Plates and Boxes.—In order to receive letters and notes left at a house without detaining the bearer till the door can be opened, a slot is usually made in the locking-rail of the entrance door and a metallic surround and flap known as a **letter plate** is fixed. The plate which covers the opening is, as a rule, hinged at the top, so that it hangs over the opening unless pushed up for the insertion of a package. Two examples of letter plates are shown in Fig. 94 (*a*) and (*b*), the one at (*b*)

FIG. 94

showing a letter plate combined with a handle used to shut the door from without. This combination is in general use for town and suburban houses.

113. In Fig. 95 are shown two forms of letter boxes which may be fixed on the inside of the door to receive the letters pushed in through the letter-plate opening. The one shown at (*a*) is of wire mesh or of expanded metal; the one at (*b*) is of thin japanned sheet metal with a transparent panel *a* of talc in the door, so that any letters awaiting removal may readily be seen. These boxes are sometimes made of wood.

114. Numbers and Name Plates.—For indicating the numbers of houses, cast-brass numbers are often screwed to the door, or plates are obtained in china or brass with the number required raised thereon, or, in the case of china, with the number in some dark colour and the ground in white. Plates of a similar kind,

with the words *push* and *pull*, may be obtained to fasten on swing doors.

Although metal plates with names are not usually included in ironmongery specifications, they find extensive use in hotels,

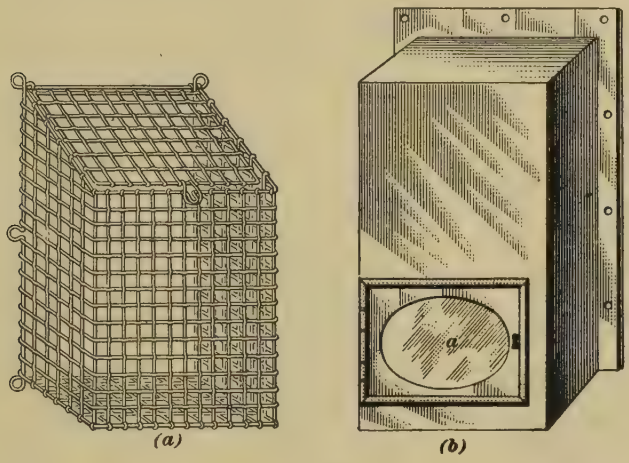


Fig. 95

banks, town halls, and other public buildings. The inscriptions cover every possible demand, including titles of officers, names of rooms, etc. Name plates of various sizes are made of bronze,

Fig. 96

brass, copper, or zinc, with either sunk or raised letters; or of white or coloured porcelain plate with black, coloured, or gilt letters. Two typical name plates are shown in Fig. 96.

115. Grip Handles.—In Fig. 97 are illustrated three types of grip handles. The handle shown at (*a*) is a brass handle with a wooden grip *a*, and has two small plates *b*, *b* for fixing to the door with screws. The handles at (*b*) and (*c*) are mounted on plates which are screwed to the door. The handle at (*c*) is fixed on the plate at right angles to its surface, but when such a handle is applied to a rather narrow stile there is a danger of

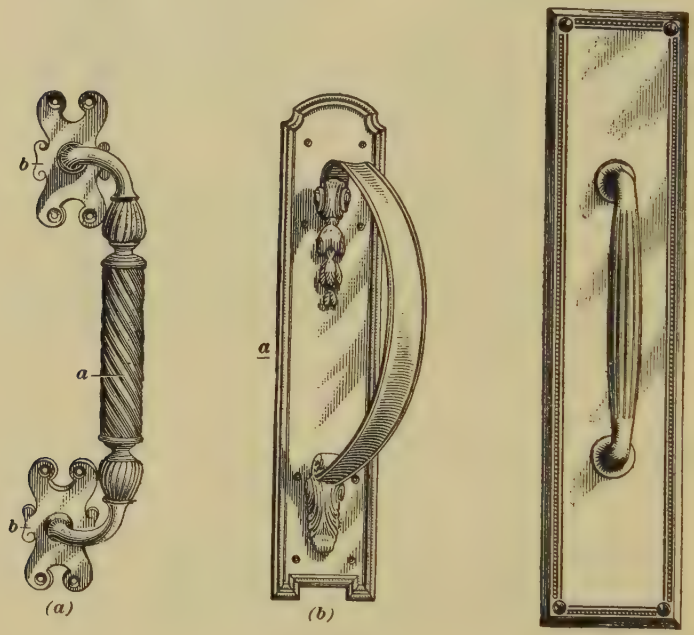


Fig. 97

the hand being trapped and coming violently in contact with the jamb, or the other leaf if they are folding doors, on account of the handle being too near the edge. To obviate this a handle such as that at (*b*) should be used where there is any danger of such an accident. Care must be taken in ordering handles of this kind to note the *hand* of the door, as a handle of this description reversed would make matters much worse instead of better. The outer edge of the stile in (*b*) would be at *a*.

When used on double-action doors, the handle has a tendency to obviate the habit of persons placing their hands on the mouldings near the glass when opening the door, but is subject to the objection of inviting a pull to open the door even with the word *push* inscribed on the plate.

Grip handles are made in various metals, both in plain and ornamental design, some of the latter being very elaborate. The actual grip part of the handle may be made of wood, as in (*a*), or of china or glass.

116. Centre Knobs and Ornamental Metal Work.—Where the entrance door to a house has a night latch operated from without only by a key, the door is shut by any person going out merely by pulling the door to behind him. As there is no knob to the latch on the outside, some other handle must be provided. This is usually done either by combining a handle with the letter plate, as shown in Fig. 94 (*b*), or by fixing in the middle of the lock-rail a massive handle, either of black iron, brass, or bronze. Fig. 98 shows a very common form of such handle, and also shows its attachment, namely, a threaded screw *a* passing through the door and secured with a nut *b* on the inside. In good work a handle of this kind may be beautifully decorated. Other forms of metal decoration may be applied to doors, such as massive iron or bronze studs which are of no constructive value in modern methods of door construction, but are used solely for decorative purposes.

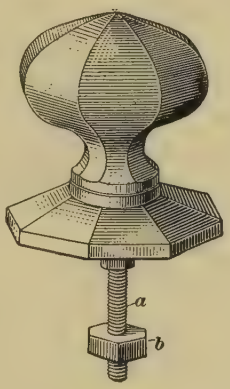


FIG. 98

117. Door Knockers.—Door knockers are probably familiar to all; though they may assume a great variety of forms, they all work on the same general principle. They are fixed by having two screws on the back, which pass through the door and are secured by nuts. They may be obtained in many designs to suit the rest of the door furniture, and they are in some cases combined with the letter plate.

BELL FITTINGS

118. Bell Pulls.—Some form of bell is, as a rule, fitted next to the entrance doors; bells are also fitted in most of the principal rooms to communicate with the servants' quarters. Two kinds of bells are still in use for these purposes: the electric bell and the old-fashioned wire-and-crank bell. Of these, the electric bell

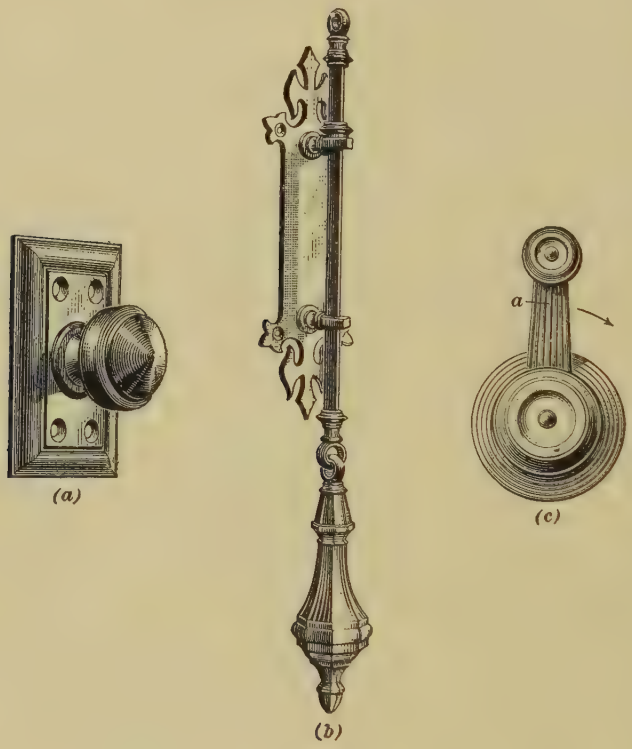


FIG. 99

can hardly be dealt with as ironmongery, but it will be necessary to describe the parts of a wire-and-crank apparatus.

In Fig. 99 are shown three types of the most usual forms of mechanism used to operate the bell. Those at (*a*) and (*b*) are used for external bells, (*a*) being pulled horizontally outwards

and (*b*) vertically downwards; both return to their original position under the influence of a spring. The bell pull illustrated at (*c*) is the one generally used for internal work, and is operated by turning the lever *a* round the centre of the bell about a quarter-turn.

119. Mechanism of Bell-Ringing Device.—In Fig. 100 (*a*) is shown a typical form of *crank* used at points where the bell wire changes its direction. In some positions a small wheel like a pulley block might do instead. The wires are attached at *a* and *b*, and if the wire *b* is pulled it rotates the crank about the pivot *c* in the direction shown by the arrow and so causes the wire at *a* to be pulled. Other forms of crank are in use for different situations, but this one illustrates the principle of action.

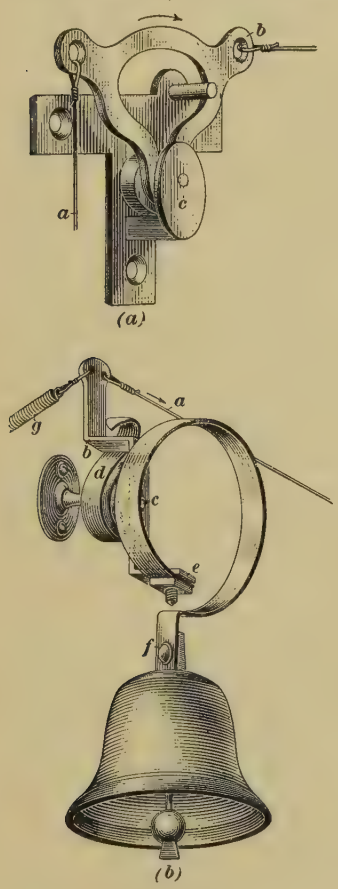


FIG. 100

In Fig. 100 (*b*) is shown the bell itself, which is usually fixed in the kitchen or servants' hall. At *a* is shown the wire, which receives a pull in the direction of the arrow; this moves the lever *b*, which is pivoted at *c* to a shank which is fixed to the wall and has a spring *d* round it, so that when the wire is released the spring and lever are agitated. At the end *e* of the lever the large scroll spring carrying the bell is fixed by means of a nut. The bell is connected to this spring at *f* by means of a copper rivet. At *g* is a check-spring to counteract the effect of the pull in the wire. The scroll spring

causes the bell to be agitated some time after the pull has ceased, and so gives time to anyone who has heard the bell, but is not actually in the room where it rang, to go and see which bell rang. For bell purposes, copper wire, 16 B.W.G., should be used.

WINDOW FITTINGS

SASH WINDOW FITTINGS

120. The term *sash* is used to denote windows which slide, as a rule, vertically. They are made in two parts, an upper and a lower sash ; if both are hung to slide, they are spoken of as *double hung ;* if only the bottom one, *single hung.*

121. Sash Pulleys.—Sash pulleys are of two kinds, *frame* and *axle pulleys.* The **frame pulleys,** generally of cast iron, have a wheel revolving on two pins, one projecting from each cheek of the case. **Axle pulleys** have a wheel revolving on an axle which passes through the wheel and the cheeks. The use of frame pulleys cannot be recommended for any work. The pulleys for the counterbalancing of double-hung, or sliding, windows, while apparently unimportant pieces of ironmongery, are worthy of much consideration in their selection, and in the preparation of the specification care should be exercised to provide the best pulley consistent with the character of the work. It is good practice to furnish the foreman joiner with a sample of the pulleys which are to be used, so that the frame will be properly mortised to receive them when the sashes are hung. By this method, the necessity of exposing the case to the weather during the erection of the building is obviated.

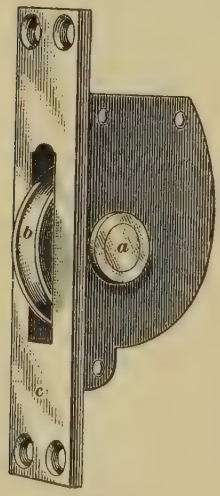


FIG. 101

Frame pulleys are rough and cheap, and are sometimes used for unimportant work and light sashes. For heavier sashes and

important work, however, only good quality axle pulleys should be used. It is important in specifying axle pulleys to stipulate the size of the pulley and to specify the diameter of the axle; also to state whether brass or bronze wheels and bronze faces are desired. Pulleys are supplied in $1\frac{3}{4}$-, 2-, $2\frac{1}{4}$-, $2\frac{1}{2}$-, and 3-inch diameters. The required diameter of the pulley is determined by the thickness of the pulley stile and the diameter of the sash weight required to balance the sash. The majority of axle pulleys are made with wrought cheeks and face plate, the cheapest being all iron, and the next in quality having a brass face plate and brass wheel, as in Fig. 101.

Fig. 101 shows the appearance of an ordinary axle pulley; *a* is the axle, *b* the projecting part of the wheel, and *c* the face plate, which is fixed flush with the outer face of the pulley stile of the sash frame.

122. In Fig. 102, a **ball-bearing pulley** is shown which works with less friction than an ordinary axle pulley, and is suitable where heavy sashes are used. At (*a*) is given a vertical section through the side of the wheel showing the balls *b* round the axle; at (*b*) is shown the elevation of the face plate. For flax lines, the edge of the wheel should be concave semicircular, as shown at *a*, but where chains are used the edge must be concave square. The face plate is sometimes made semicircular at the ends, so that the sinking for it may readily be formed by means of a bit.

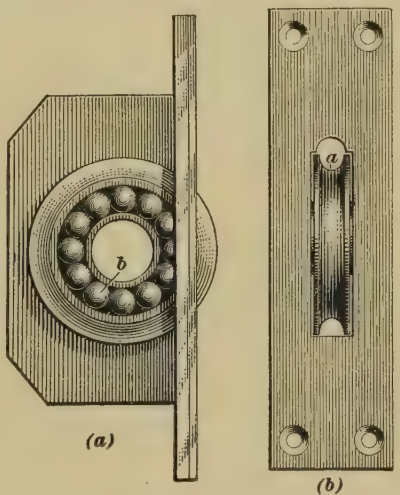


Fig. 102

123. In Fig. 103 (*a*), (*b*), and (*c*), a special form of roller axle pulley is shown for use with very large and heavy sashes; the roller *a*

over which the cord passes has, in addition to its bearing on the axle *b*, a bearing on the small roller at *c*. The face plate *d* is of brass and the roller and wheel of gunmetal, for durability. An improvement on this by the same makers has the wheel of aluminium or an aluminium alloy, which, being a softer metal, allows the wheel under the pressure on it to adjust itself to the roller, which is of gunmetal. The face plate is also of aluminium, which does not readily tarnish or corrode.

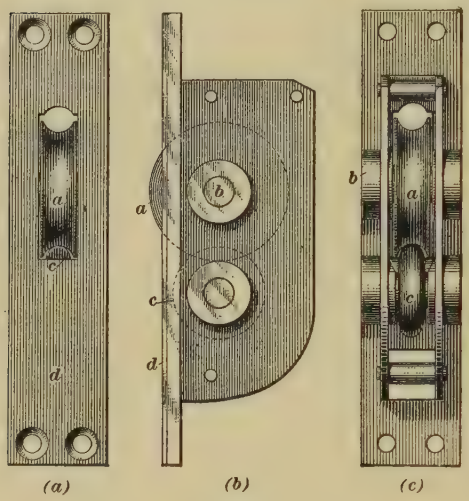


FIG. 103

124. In positions where two sash windows are fixed together, and it is desired to have only a narrow mullion between them and not to have a frame wide enough to accommodate the weights of the windows on either side, an arrangement similar to that shown in Fig. 104 (*a*) must be adopted. The cord or chain from the side of the sash which adjoins the next sash passes through the top lining over a pulley wheel and then horizontally to the jamb frame, where it passes over another wheel and then goes down the pocket where the weights hang. In this case, each pocket at the side of the double window must be made sufficiently large to accommodate all the weights for the window adjoining it. At (*b*) is shown the same principle applied to a position where the weights have to be brought down on one side only of the double window.

125. The architect's specification should stipulate the diameter of the sash pulleys to be used in the work, and this item requires careful consideration. Where care is not exercised in

this regard, either the pulleys will be so small that the weight will rub against the pulley stile, or they will be so large that the weight will rub the frame casing on the opposite side of the pocket. Standard sash pulleys are made in sizes from $1\frac{3}{4}$ to

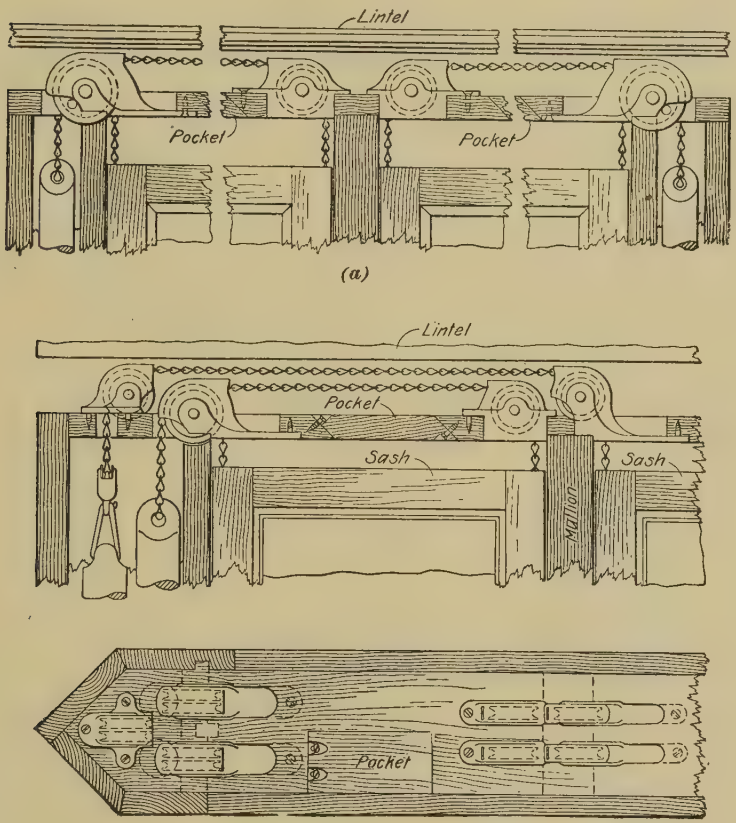


Fig. 104

3 inches in diameter, varying by quarter inches. In determining the diameter of the pulley required for a particular window frame, the thickness of the pulley stile must be taken into account. The outer face of the pulley may be considered to project $\frac{1}{4}$ inch beyond the face of the pulley stile in front; and

behind, it should project such an amount as will cause the cord to hang in the centre of the pocket for the weight, or at least allow the weight to hang free of the sides of the pocket.

126. Sash Cords and Chains.—The **sash cords** by which the sashes are attached to the counterweights in double-hung windows are usually furnished by the carpenter, and are so specified. However, they may be referred to under ironmongery. The specification for the sash cord should state both the size and the maker's name, and for good work *Austin's* or *Samson Spot* sash cords are among the best that can be procured. Table IV

TABLE IV

STANDARD SIZE OF SASH CORD FOR PULLEYS

Size Number of Samson Spot Cord	Diameter of Cord Inch	Heaviest Weight to be Used on Each Line Pounds	Diameter of Smallest Pulley to be Used Inches
6	$\frac{3}{16}$	5	$1\frac{1}{2}$
7	$\frac{7}{32}$	15	$1\frac{3}{4}$
8	$\frac{1}{4}$	25	2
9	$\frac{9}{32}$	35	$2\frac{1}{4}$
10	$\frac{5}{16}$	45	$2\frac{1}{2}$
12	$\frac{3}{8}$	55	3

will be found convenient in determining the diameter of the cord, as well as the size of the sash pulley. The size numbers given are those of Samson Spot cords; the numbers of other makes are different.

127. In Fig. 105 (*a*) are shown various forms of **sash chains**; they may be had either in steel, brass, or copper. The hook *a* shown at one end of the chain is for attaching to the weight; the plate at the other end is to be screwed to the side of the sash. The sash chains on the market are usually made in five sizes, and specified by size numbers. The makers, however, have no agreement regarding these standards, so that the numbering is not

uniform; one manufacturer's No. 3 chain may be his heaviest make, while a chain of the same number furnished by another maker may be the lightest chain that he manufactures. In order to provide against this discrepancy when specifying, it is well to name the maker of the chain. The lightest sash chain will support sashes weighing from 40 to 75 pounds, while the heaviest will carry sashes that weigh from 150 to 250 pounds.

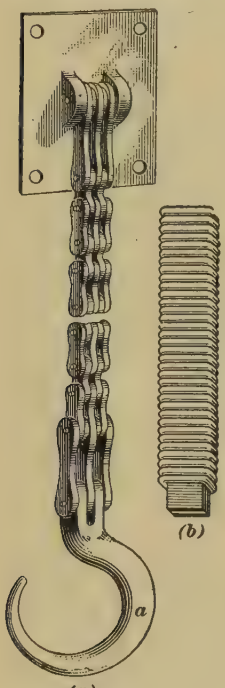


Fig. 105

In Fig. 105 (*b*) is shown another form of sash support, known as *Hookham's steel-ribbon sash line.* It consists of two or three steel tapes closely bound round with copper wire.

128. **Sash Balances.**—By the use of **sash balances,** one of which is shown in Fig. 106, there is no necessity for weight boxes, counterweights, etc. The contrivance illustrated has been manufactured for many

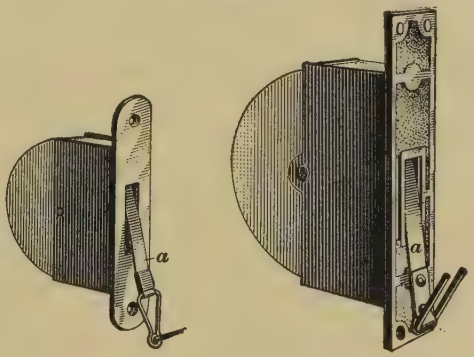


Fig. 106

years, and the original intention was to have it displace the sash pulley, cord, and weight for double-hung windows. Installing spring sash pulleys costs more than the older method of hanging by means of counterweights. They are constructed with a long, spiral spring enclosed by a drum, on which the tape *a*, Fig. 106, winds and thus raises the sash. The coil spring in this balance is made of either light or heavy material, according to the weight of the sash it is intended to counterbalance.

They are seldom used, however, except where there is insufficient room for sash weights. The steel tape is liable to be twisted and broken by jarring in operating the sash, and for general use it has been found that the most positive action is secured by pulleys and weights.

Other methods are adopted to avoid the use of cords and weights in sash windows. These consist generally of various appliances to increase the friction between the sash and its frame, such as rollers in the frame pressed strongly against the side of the sash by means of a spring.

129. Weight of Sash and Glass.—In estimating the weight of window sashes, in order that the size of the counterweights or of the spring counterbalance may be determined, the weight of the glass per square foot may be taken as follows: Plate glass, $3\frac{1}{2}$ pounds; blown plate glass, $1\frac{1}{3}$ pounds; and ordinary sheet glass, 1 pound or $1\frac{1}{3}$ pounds. To find the weight of the wooden sash, add together the height and the width of the sash, in feet, and multiply by 2·1 for $2\frac{1}{4}$-inch sash, by 1·67 for $1\frac{3}{4}$-inch sash, and by 1·33 for $1\frac{3}{8}$-inch sash, the result being approximately the weight in pounds. The several sizes of sash given indicate the thickness of the sash frame. While these data for determining the weight of sash are not exact, they are sufficiently accurate to fix the size of the sash cords and pulleys and to estimate the weight required to counterbalance them. The best practice, however, is to weigh each sash after it has been glazed; in this manner the exact weight and size of the counterweights required can be determined.

130. Sash Fasteners.—There are many different makes of sash fasteners for double-hung sashes in the market. In Fig. 107 are shown several types which have been used extensively. The fastener shown at (*a*) is known as Hopkinson's, having a bevel *a* on the arm which prevents it from being pushed back by a knife inserted between the sashes. At (*b*) is shown a burglar-proof sash fastener. The upright portion *a* of the looped handle is an eccentric; consequently, when the handle is turned, the cross-bar *b* is drawn forwards and the two sashes tightly jammed. At (*c*) is shown a sash fastener known as the

Fitch. This fastener is made by several manufacturers, and can be procured in all finishes of iron for the cheaper class of buildings, and also in bronze metal for high-class work. It is composed of a helical cam, which is fastened to the top of the meeting rail of the lower sash and engages with a hook, or lug,

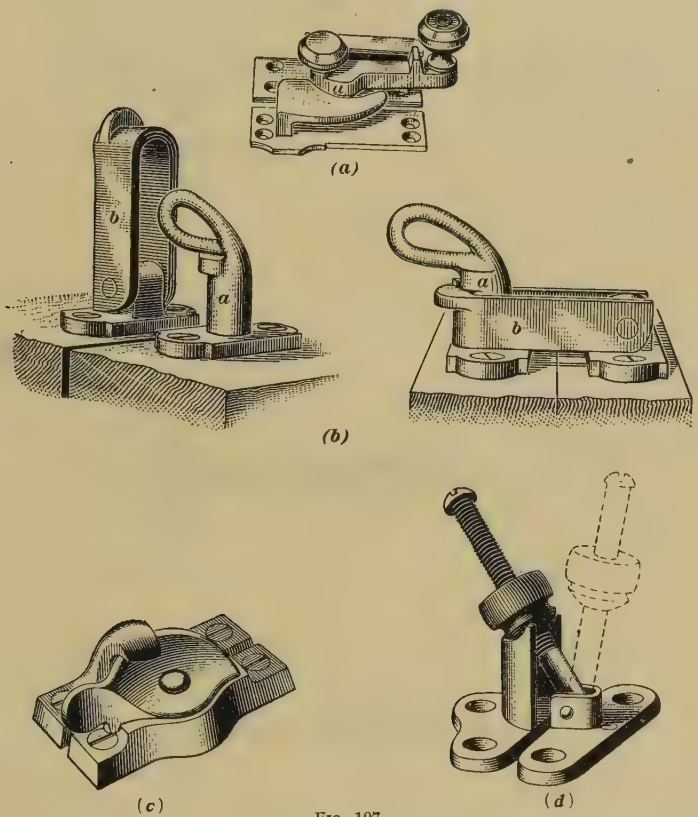


FIG. 107

that is secured to the bottom of the upper sash. The operation of this fastener is rapid, and the rotary movement draws the two sashes together horizontally and forces them in opposite directions vertically. In this way, it holds the sash fast and prevents rattling and draughts. It cannot be moved by inserting a knife blade between the sashes from the outside. The *screw*

sash fastener illustrated in (*d*) accomplishes the same results as the Fitch fastener; namely, drawing the sash together by the tightening of a thumb nut on a fine-pitched screw. This nut operates against a shaped hook, or lug, on the lower sash, thus developing great pressure in the desired direction. While this

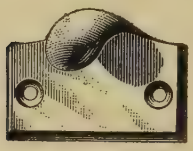


FIG. 108

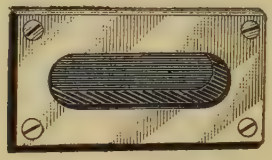


FIG. 109

sash fastener takes somewhat longer to operate than other patterns, it provides greater security.

131. Sash Lifts.—**Sash lifts** are not usually provided for the cheapest work, as the window can be raised by pushing against the parting rail or against the glazing bars; but this is apt to

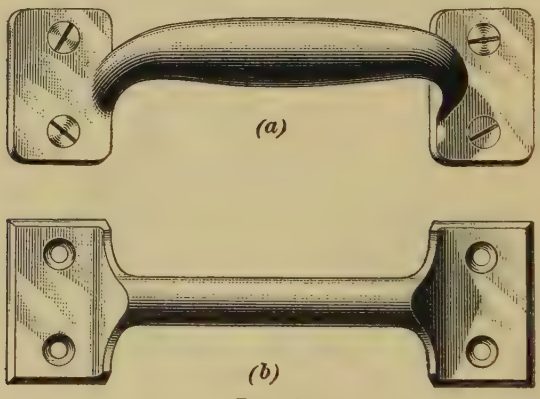


FIG. 110

draw the woodwork away from the glass, and as sash lifts are made to sell at such reasonable prices, it would seem advisable to place them on the lower sashes of all buildings, no matter how unimportant.

The common type of sash lift illustrated in Fig. 108 is known as the *hook sash lift*. This lift is extensively used, and can be

procured in any quality or weight, in either brass or bronze metal, and in any finish desired.

The *flush sash lift*, the general type of which is shown in Fig. 109, is considerably stronger than the hook lift, from the fact that the casing forming the grip is let into the lower rail of the sash, and the strain is taken by this, rather than by the screws ; but it is more expensive to fix as it involves cutting the woodwork. These lifts are made in either brass or bronze, and in all finishes.

For sashes such as those in public and office buildings, the *bar sash lifts* illustrated in Fig. 110 (*a*) and (*b*) are the best. This type of lift should always be used for heavy sashes. A sash lift similar to the type shown at (*a*) is sometimes fastened to the under side of the meeting rail of the upper sash for the purpose of lowering the sash.

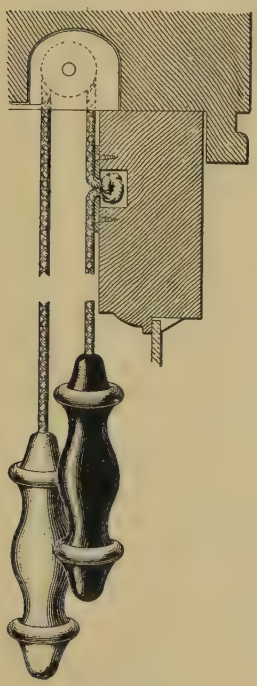


Fig. 111

For moving the upper sash where the sash is rather large or high up, an arrangement of cords similar to that shown in Fig. 111 may be adopted with advantage. The cord with a white handle passes over a pulley and serves to pull the sash up ; the one with a black handle attached directly to the sash serves to draw it down. A cord arrangement of this kind must be fixed on each stile of the sash.

132. Pole, or Long-Arm, Hooks and Sash Eyes.—In rooms having high ceilings, where the top sash is some distance from the floor, as in institutions, schools, and factories, it is necessary to provide *pull-down poles*, or *long-arms*, for the purpose of raising and lowering the upper sash. The hooks used on the ends of such poles, which are made of some tough wood, are illustrated in Fig. 112 (*a*) and (*b*). Unless the upper sash is furnished with

metal plates having a hole or ring, the pole will be used against the upper rail or glazing bars of the window sash and thus mar the woodwork. The plates, or rings, to engage the pole, or long-arm, hooks are illustrated in Fig. 113. They may be had in all metals and finishes and in several sizes.

133. Casement-Window Fittings.—The term *casement* applies properly to any hinged sash. Where the casement extends to the floor, the term *French window*, or *French casement*, is generally used. In designing casement windows, the details of the fittings should be such that the casements can be made weather-tight ; and in preparing the full-sized details for the joinery, the available fittings should be studied, so that the woodwork may be arranged to conform to them.

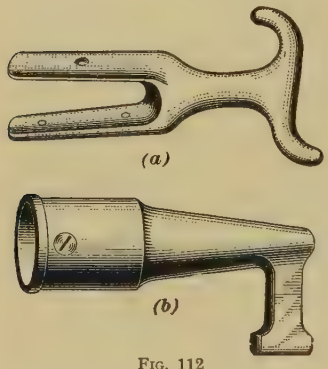


Fig. 112

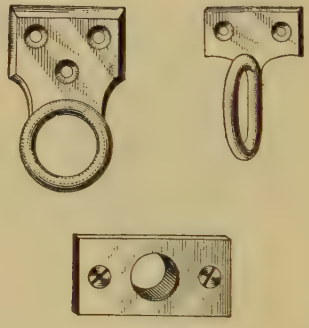


Fig. 113

134. Hanging Appliances.—Side-hung casement windows are usually hung on butt hinges, but a type of hinge that is also used for casements in certain positions is illustrated in Fig. 114. Two views from the outside are shown at (*a*), the hinge being a form of projecting casement hinge that might with advantage be used for windows in positions where it is difficult to get at the outside for cleaning purposes. At (*b*) is shown a plan, the dotted lines showing position of casement when open, from which it will be seen that the casement *a* when open is so far from the mullion or frame *b*, to which it is hung, that the arm may be put through and the outside of the glass readily cleaned. Other forms of hinge are made which allow the casement to be

quite reversed, so that the cleaning process is easier still; but these are generally cumbersome and expensive and, moreover, liable to sag.

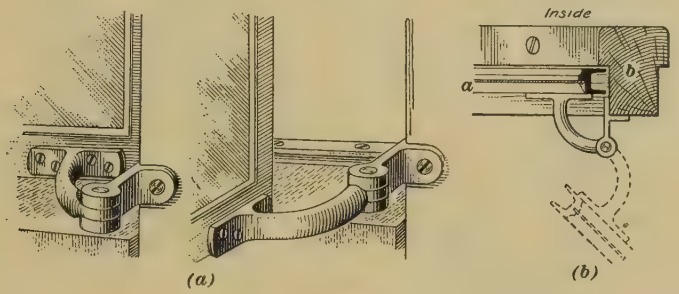


Fig. 114

135. Casements may sometimes be hung on **pivots** about which they revolve, instead of being hung on butts. These pivots may be attached to the top and bottom of a casement, so that it revolves but is always vertical; this arrangement is not, however, very usual. Fanlights and casements high up are often hung on centres placed at the sides, so that they occupy oblique positions, except when closed. Fig. 115 illustrates types of pivots and centres in general use.

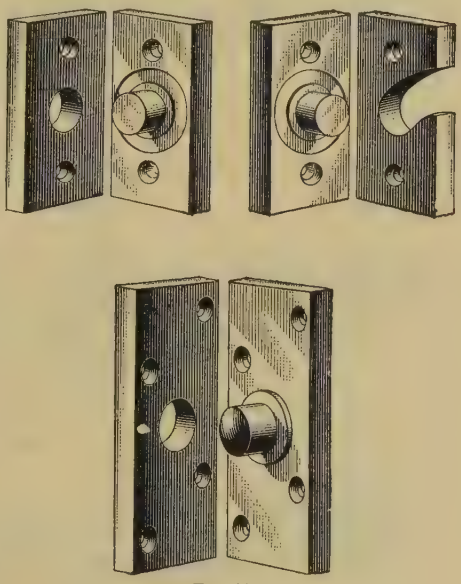


Fig. 115

136. Casement Stays.—In order to hold pivoted or hinged casements in a partly open position, it is necessary to use **casement stays,** the method of applying which is illustrated in Fig. 116.

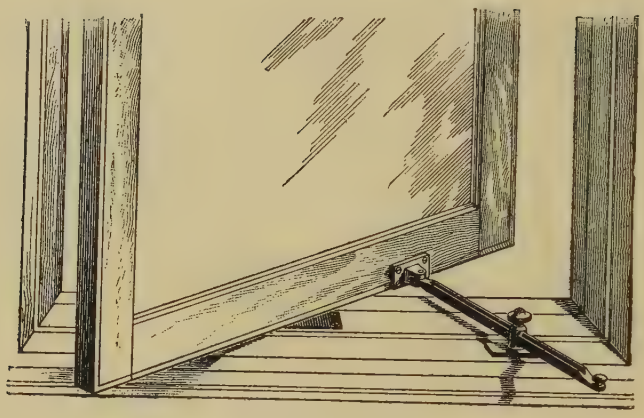


Fig. 116

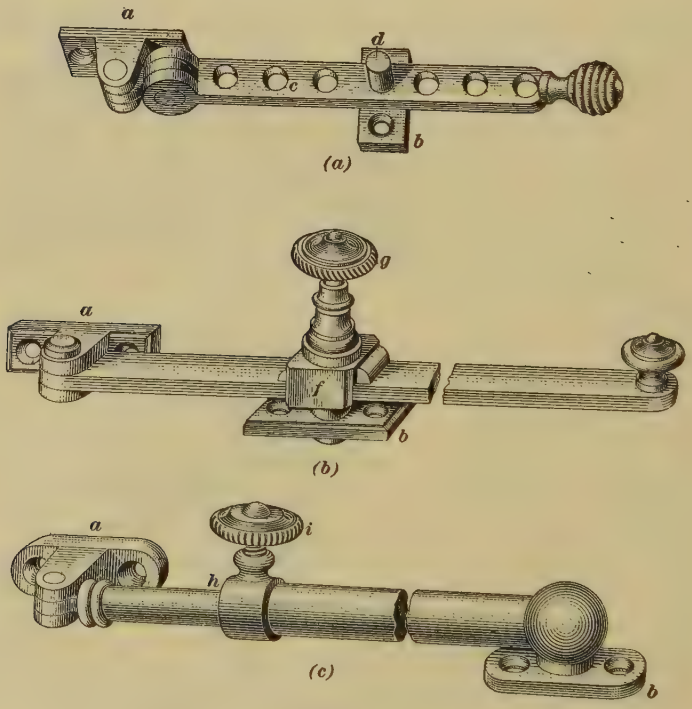


Fig. 117

In this illustration the stay is shown applied to a casement pivoted at the top and the bottom, but the device can as well be applied to a casement hinged at the sides.

There are many forms of casement stays, the three principal types being illustrated in Fig. 117. They are arranged for casements that open either inwards or outwards, and may be applied to either pivoted or hinged casements. At (*a*) is a **pin stay,** at (*b*) a **sliding stay,** and at (*c*) a **telescopic stay.** In each case, the part at *a* is secured by screws to the casement and the part at *b* to the sill, the stay having a pivoted joint to the casement. The pin stay has a series of holes *c* in the stay, which fit over a pin *d* on the sill. The sliding stay passes through a clamp *f* with a screw *g* to hold the stay in any position. The telescopic stay has a pivot joint at each end, and the length of the stay is regulated by one part sliding in the other at *h* and being secured by a screw *i* in any position. With a casement opening inwards, a form of sliding stay may be used in which the stay is fixed to the sill and the clamp to the casement.

In the case of small or unimportant windows, a hook-and-eye stay may be used, as shown in Fig. 118. In this case the hook *a* would be attached to the sill, outside for an outward-opening casement, and the eye *b* to the casement. Two eyes may be secured to the casement, if desired, so that the window may be held in either of two positions.

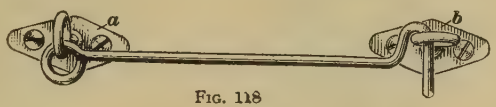


Fig. 118

137. Cockspur Fasteners.—Casements may be provided with any good form of top and bottom bolts, but the most usual form of fastener is the **cockspur;** this device is fixed on the casement, and there is a striking plate to match fixed on the frame. Three typical forms of cockspur fastener are shown in Fig. 119. A plain handle is shown at (*a*); at (*b*) and (*c*) a handle is shown in elevation and plan to illustrate the form of sweep which brings the handle well away from the glass. At (*d*) is shown a more ornate example. The example shown at (*b*) and (*c*) is fixed to a wooden casement, but such handles may be fixed to metal as well. The

example at (*d*), if fixed to a metal casement, would have the pieced plate over the glass, the line of the frame being about as indicated. Handles of this kind can be obtained in black wrought iron, brass, or bronze.

Where French windows are in use, if they are of wood, the fastening may consist of an ordinary mortise latch with handle

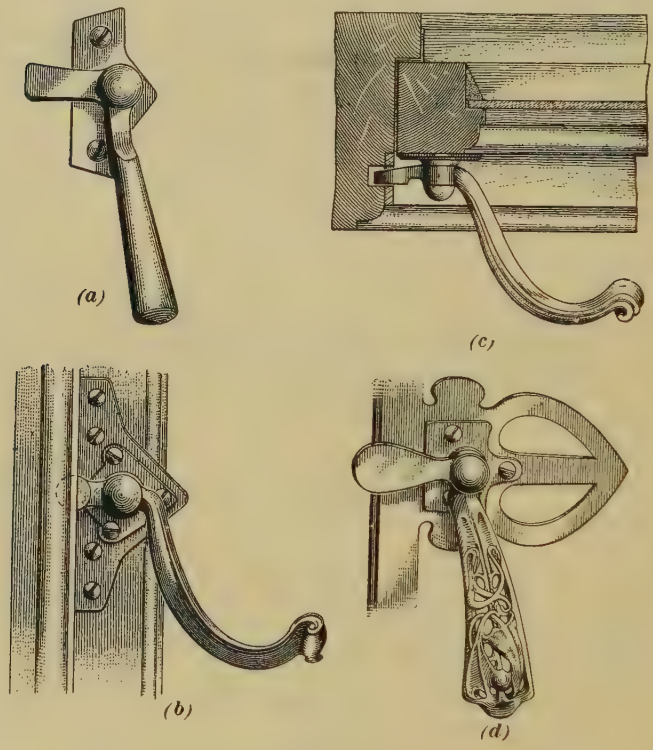


Fig. 119

and key, and, in addition, one bolt at the top and another at the bottom; but, as a rule, in good-class work, windows of this kind would be provided with one or the other of the forms of bolt now to be described.

138. French Bolts.—A **French bolt** consists of a vertical rod divided at or about the middle of its length, thus making two

pieces, and is operated by a knob, or handle, at that point. Types of French bolts are illustrated in Fig. 120. As shown, the upper and lower ends of the rods, or bolts, slide vertically and in opposite directions, being operated by the turning of the knob, or handle. These bolts are furnished with suitable striking plates or sockets, which are attached to the window frame at the top and bottom. The ends of the bolts are bevelled, or rounded, thus pressing the two casements tightly together and against the frame when they are thrown in. A single movement of the knob, or lever handle, is sufficient to release both bolts.

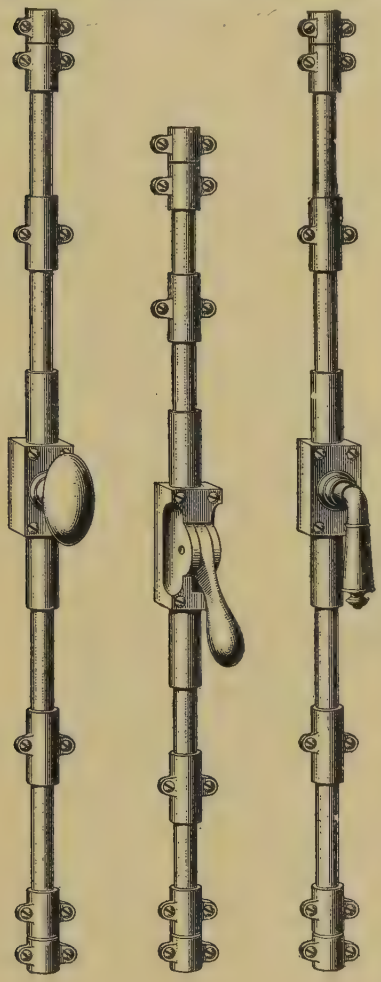


Fig. 120

139. Espagnolette Bolts. In Fig. 121 is shown the **Espagnolette bolt,** which differs from the French bolt, in which the vertical rod is in two pieces, which are shot in opposite directions by the action of the handle and mechanism. The vertical rod in the Espagnolette bolt is in one piece. This rod has hooks at each end, and, by a rotary motion, engages pins, or plates, in the window frame, thus drawing the sashes together and against the frame. These bolts are usually operated by a pendant handle, which, when lifted, will release the rod so that it may be rotated to fasten or to release the casements. The pendant handle may

be made to pass behind a tapered hook on the other leaf of the window when the window is closed, which gives additional rigidity to the fastening. The Espagnolette bolt is usually heavier than the French and exerts more power in forcing the sashes against the frame ; it is also more expensive. Both bolts, however, are available for use on doors as well as on windows, and lend themselves admirably to decorative treatment.

Fig. 121

The same care should be exercised in the selection of these bolts as for other ironmongery, and, when ordering them, full-sized details should accompany the order, showing sections through the top and bottom and meeting rails, and the head and sill. The exact measurement of the height and the width of the openings should also be given, and the information should state whether the window swings inwards or outwards. The hand of the active leaf, as well as the height of the handle from the floor, should also be given. In Fig. 122 are shown sections through a French casement opening inwards, upon which Espagnolette bolts are to be fitted. Sections similar to these should be furnished to the manufacturer, so that the bolts will fit their intended situation in the building.

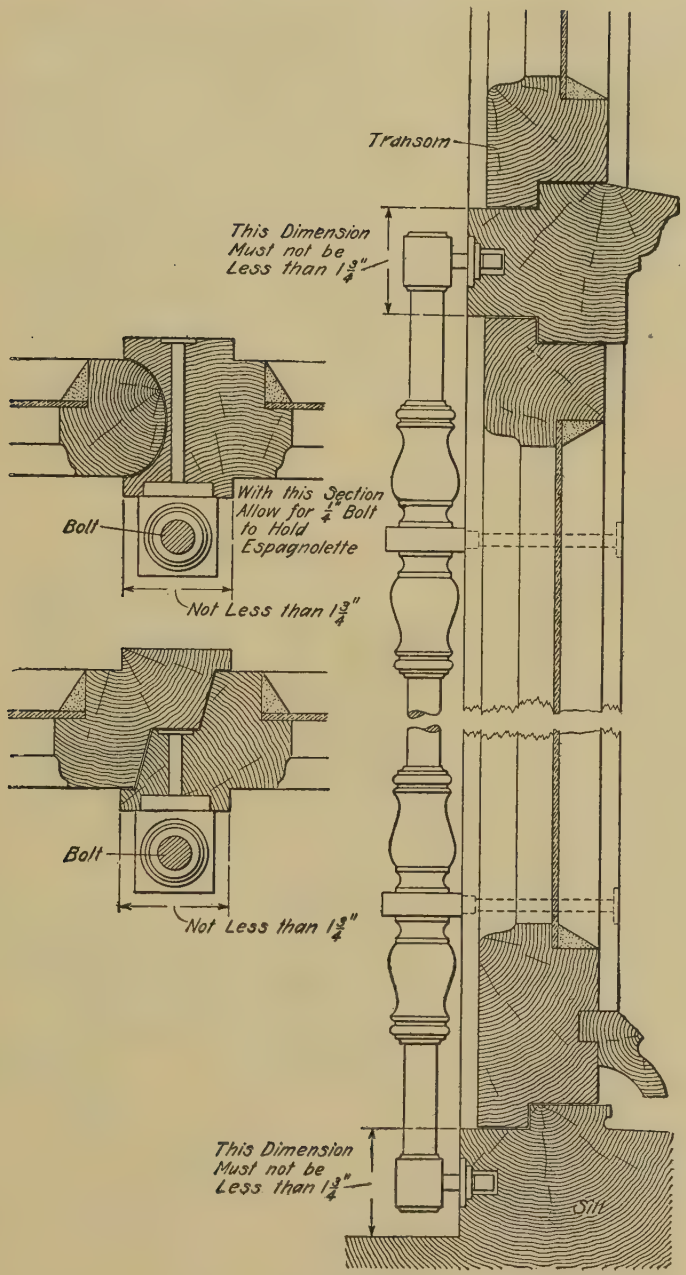

Transom
This Dimension Must not be Less than 1¾"
With this Section Allow for ¼" Bolt to Hold Espagnolette
Bolt
Not Less than 1¾"
Bolt
Not Less than 1¾"
This Dimension Must not be Less than 1¾"
Sill

FIG. 122

140. Hanging of Fanlights.—Casement windows that are rather high above the floor, or over a transom or door head, are, as a rule, hung on pivots and open in one or the other of the ways shown in Fig. 123. At (*a*) a light is shown hung at the bottom to open inwards; at (*b*) the light is centre, or pivot, hung; and at (*c*) is shown a light hung at the top to open outwards. Lights of types shown at (*a*) and (*c*) are hung on ordinary butts, while lights of the type shown at (*b*) are hung on pivots and centres.

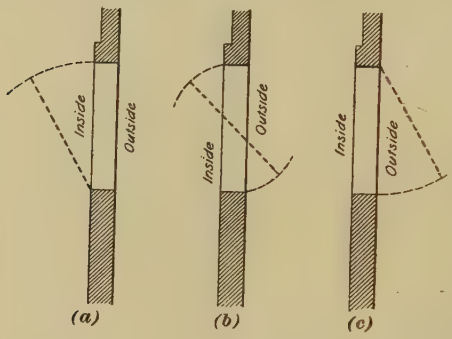


FIG. 123

141. Fanlight Catches.—In Fig. 124 are illustrated types of **spring fanlight catches, or bolts.** These devices are provided in the several forms shown to meet various conditions. Those shown at (*a*), (*b*), and (*c*) have a ring, or eye, in the handle, to which an operating cord may be attached, or into which a pull-down hook may be inserted, to operate the sash. The fanlight catch at (*d*) is made expressly for operation by means of a pull-down hook. In very wide windows, for the purpose of limiting the opening of the

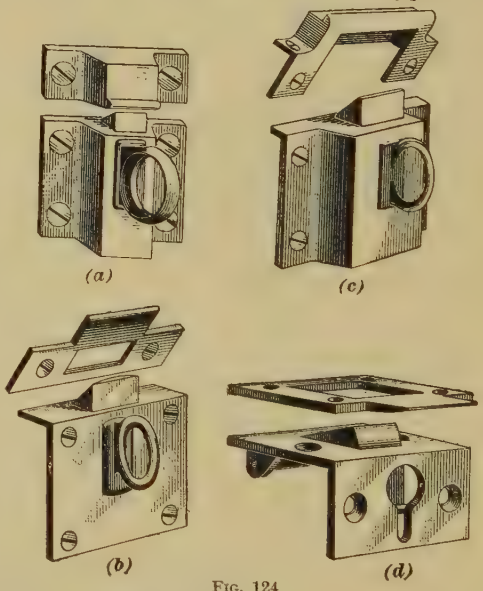


FIG. 124

sash, these catches should be used in conjunction with quadrants instead of with opening gear.

142. Fanlight Stays.—In Fig. 125 are shown the more usual forms of stays used to prevent inward-opening bottom-hung casements from opening too far. At (*a*) is shown a **quadrant stay,** on which a small catch *a*, attached to the top of the fanlight, moves ; the end *b* is bent, so as to prevent the fanlight from slipping off and falling down. The catch would need to be operated by a long-arm hook or similar contrivance. At (*b*) is shown a fanlight fitted with **shad-bolt stays.** These are thin flat metal bars having a slot in which a screw or pin in the side of the casement moves. This form of stay allows the fanlight to take only two positions : shut and wide open. However, a form of stay may be used which has notches in the slot in which the pins of the fanlight can catch. At the top of the light would be fixed a small catch or some form of cord gearing, as described later. At (*c*) a chain is shown which might be used for fanlights, one end being attached to the light and the other to the frame to prevent the light from opening too wide ; a catch or cord gear would be used in connection with this as with the shad-bolt.

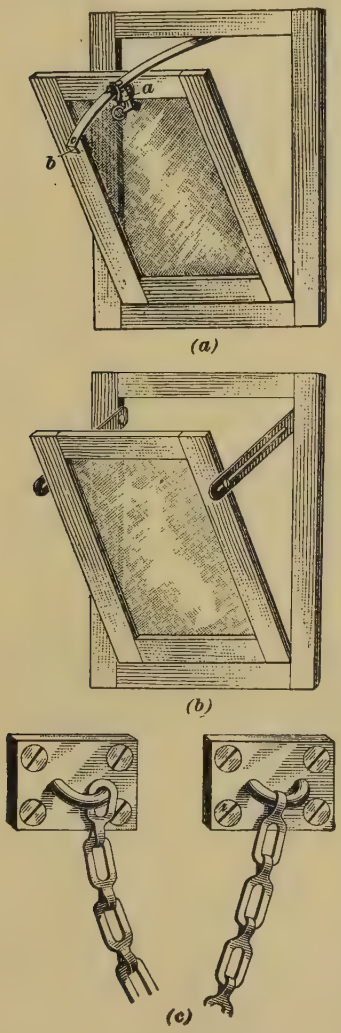


Fig. 125

143. Cord Opening Gear.—For operating casements that are out

of reach of the hand, two forms of mechanism, termed *cord gear* and *rod gear*, are usually employed.

In Fig. 126 is shown a form of cord gear consisting of an endless cord *a* which rotates a small wheel *b*, which in turn actuates a worm-gear *c*, which moves on a toothed quadrant stay *d*. This form of gear can be applied to a pivoted fanlight, and also to a top-hung outward-opening light; but in this case the stay would be fixed to the bottom of the light, and the worm-gear and wheel to the sill or transom.

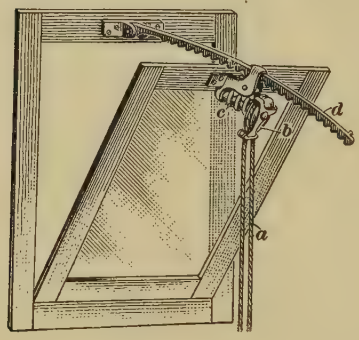


FIG. 126

144. Another method of operating a fanlight by means of a cord is shown in Fig. 127. In this case, no stay is used, and to keep the fanlight in any particular position the cord must be made fast to a cleat, and a chain or shad-bolt stay must be provided as a check against opening too far. The working of this device will be plain from Fig. 127. At (*a*) and (*b*) sections are given showing the light closed and partly open, respectively; at (*c*) an inside elevation

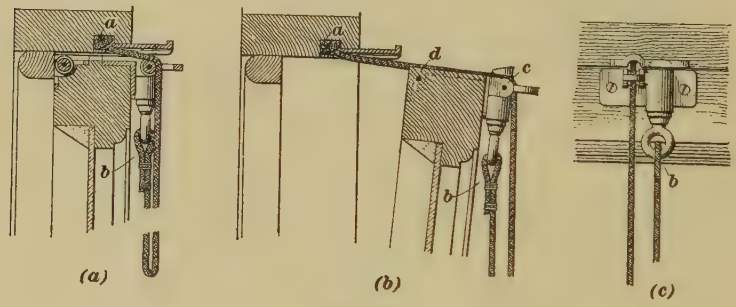


FIG. 127

shows how the cords hang apart from each other and are not liable to become entangled. The end *a* is fixed to the head of the window, the end *b* to the head of the light; the cord from *a* passes over the pulley wheel at *c*, and when the light is open

the one at *d* also, to prevent wearing from friction. When this cord is pulled, the effect is to close the light ; if that attached to *b* is pulled and *a* released, the light will be opened. This kind of gear may be applied to centre-hung or bottom-hung lights.

145. Rod Opening Gear.—In Fig. 128 is illustrated a typical form of rod gear. The rod *a* is moved up or down by some simple form of mechanism, as described later, and this, by raising or lowering the end *b* of the lever *c*, which is rigidly attached to the horizontal rod *d*, causes the rod *d* to rotate. As shown, the fanlight is open ; but if the rod *d* is rotated in the direction shown by the small arrow at *e*, the bars *f*, *f*, which are rigidly attached to *d*, will also rotate about the axis of *d* and take a vertical position and then come still farther inwards, drawing the fanlight to a closed position by means of the bars *g*, which are hinged at *h* and *i*.

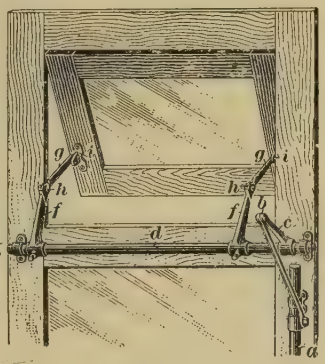


Fig. 128

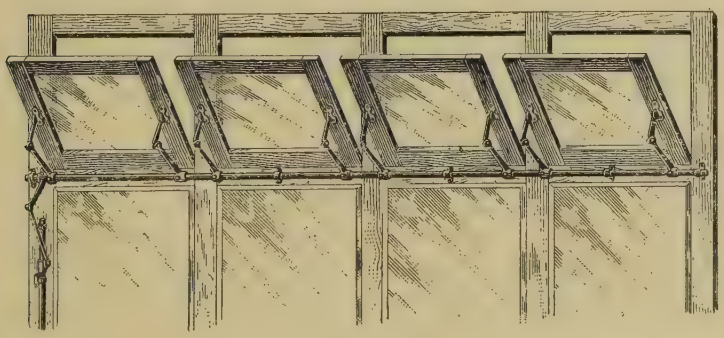


Fig. 129

146. In Fig. 129, a similar kind of gear is used to operate a row of fanlights, but in this instance the lights are hung at

the bottom to open inwards. Precisely similar gear may be used to open windows that are centre-hung. A system of this kind may also be used to work several tiers of such windows.

147. By a somewhat more complicated system of rods, this kind of gear may be applied to clerestory or roof lights, with the operating gear fixed on the surface of the wall in a convenient position, as shown in Fig. 130 (*a*). Undue multiplicity of rods, however, becomes unsightly, so the best form of gear for such a situation would be the cord-and-rod arrangement shown at *b*. The endless cord *a*, when pulled, rotates a small wheel *b*, which actuates a worm-gear *c*. This turns the rod *d*, to which the arms *e* are fastened. As the rod *d* turns, the arms move outwards and push open the sashes.

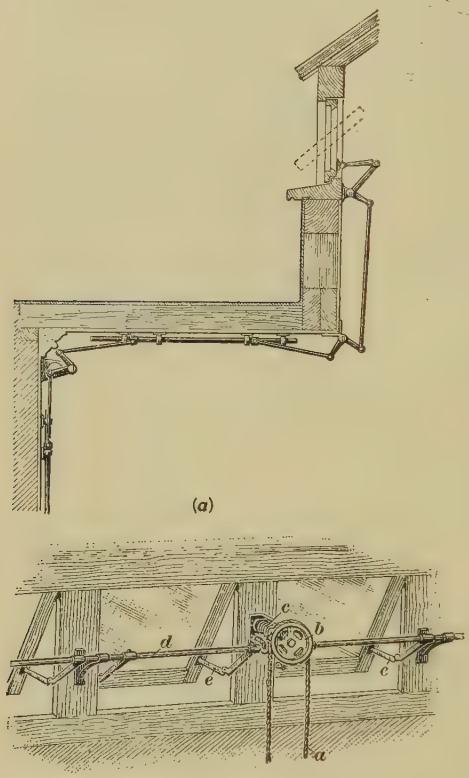


Fig. 130

148. Mechanisms for Operating Rod Gear. Three kinds of mechanical contrivances are in use for operating the rod gears already illustrated. By far the most usual, and probably the best, is the screw arrangement shown in Fig. 131. The handle *a* is turned, and by means of a bevelled cog-wheel this turns the threaded rod *b*, and so moves it up or down. The small stops *c*, *c* prevent the rod from being screwed too far in either direction.

In Fig. 132 a lever mechanism is shown. The rod *a* passes through the guides *b*, *b*, but has a fixed connection *c*, to which a secondary rod *d* is fixed by a hinged joint. This rod *d* is moved up or down by means of the lever handle *e*, which is pivoted at *f*.

In Fig. 133 several forms of light gear for fanlights over internal doors are shown, the rod *a* acting on the arm *b* being controlled in this case by a spring clamp at *c*. The rod is simply pulled a little forwards and moved up or down, the spring holding it in the position where it is left. This form of mechanism is suitable only for operating a single window. For any large or heavy work, or several lights, the only really suitable mechanism is the screw contrivance described first.

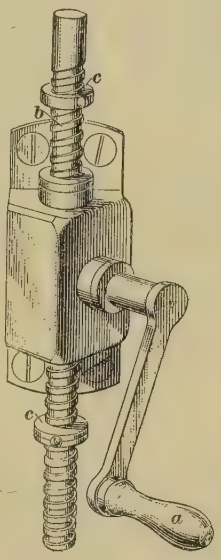


Fig. 131

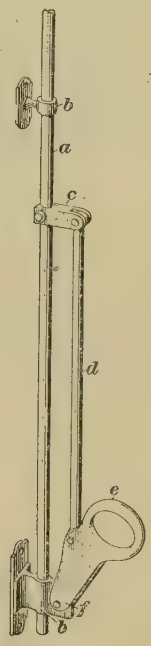


Fig. 132

149. Weather Bars.—For wooden casements in situations particularly exposed to driving rain, an arrangement of metal bars or strips is sometimes used to act as a check against the entrance of water or draught. In Fig. 134 three applications of these bars are shown : at (*a*) the bars are applied to the sill of a casement which opens outwards, with one bar screwed to the sill and one to the casement in a way that would tend to prevent water driven by the wind from forcing its way in; at (*b*) the bars are applied to the sill of a casement that opens inwards ; at (*c*), to the meeting stiles of folding casements. In the last case it will be observed that the metal strips entirely replace the rabbet and beads usual in such a position. The aim in arranging these bars should be to contrive as many corners as possible where the water entering must double back on its previous

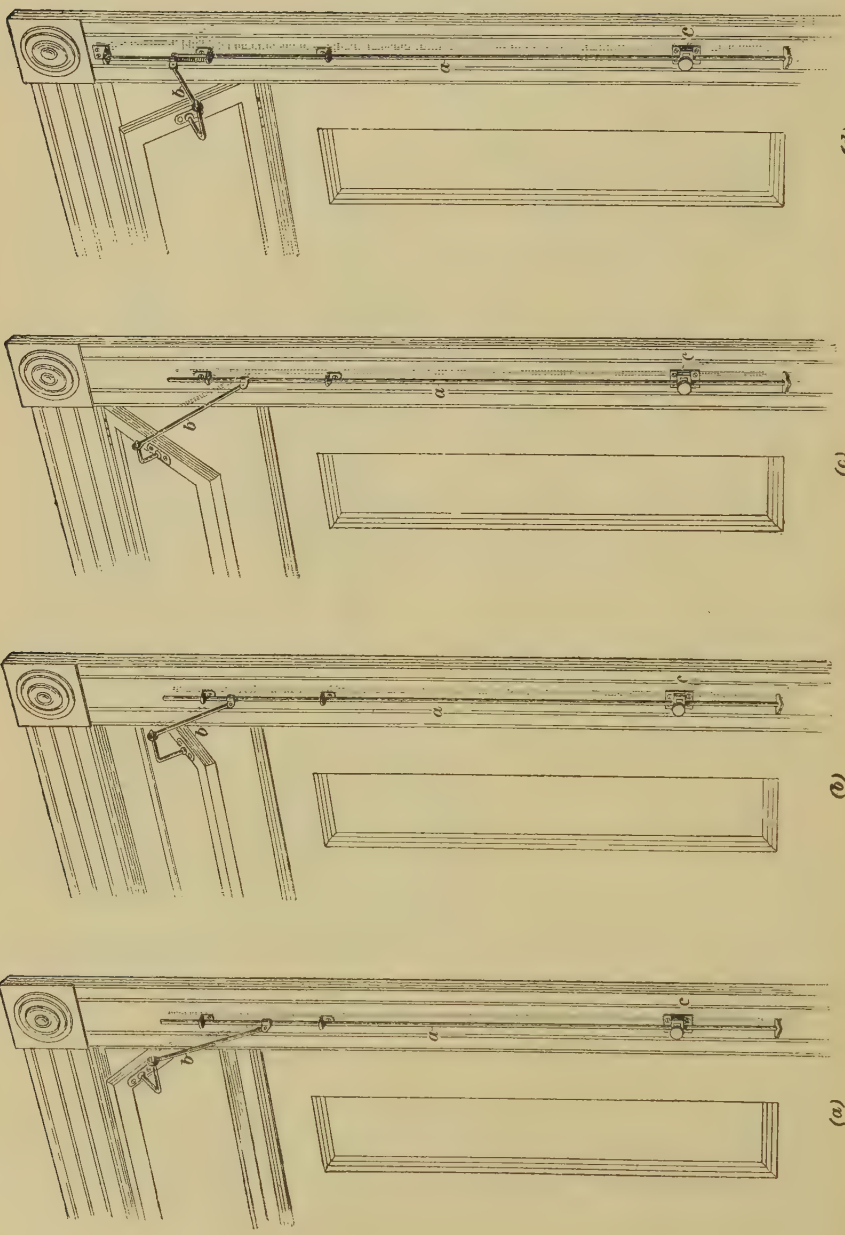


FIG. 133

course, and to provide spaces for the collection of water and the expenditure of draughts. If a certain number of these spaces

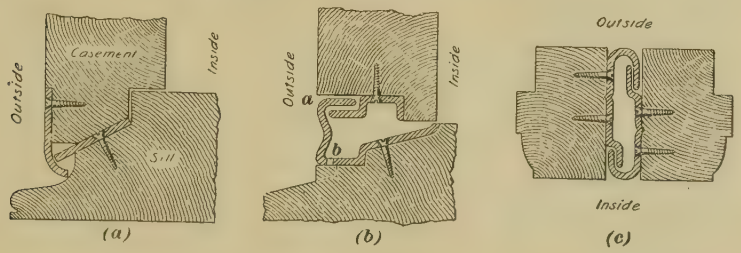


Fig. 134

are not provided, the water may gain admittance by a kind of capillary attraction.

MISCELLANEOUS IRONMONGERY

150. Staircase Hand-Rail Brackets.—Where a flight of stairs is next to a wall and a hand rail has to be provided, it may be fixed on wrought-iron hand-rail brackets, as shown in Fig. 135. At (*a*), an example is shown attached to a plate which would be screwed to plugs in the wall or a wooden fixing block; the

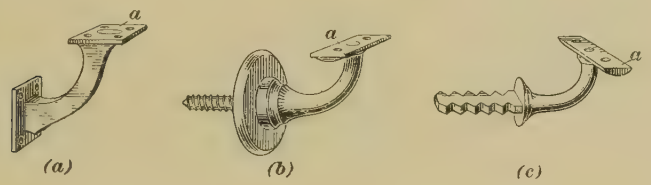


Fig. 135

example at (*b*) has a screw formed on the end, so that it may be screwed direct to a plug. These brackets are also made as at (*c*), with a lug on the back for building into the wall. The plate *a* in each case is screwed to the under side of the hand rail.

151. Stair Treads.—In cases where public staircases are subjected to much wear, such as steps to underground railways, some form of stair tread is usually inserted into the stone or

concrete steps. The idea is that the metallic tread will wear less rapidly, and when worn may be more easily renewed, than stone or concrete steps. It is claimed for most treads of this kind that they are not slippery, but, as a matter of fact, those that consist merely of corrugated, or otherwise roughened, surfaces of steel or brass, as in Fig. 136 (*a*), become polished and very slippery. At (*b*) is shown an illustration of a tread composed partly of steel and partly of lead, the darker parts in section showing the lead. Lead is about the least slippery substance that can be found, but it wears quickly. It is, however, claimed for some of these treads, formed of a hard and soft substance combined, that the wearing of the soft substance leaves the edges of the hard metal sharp and so prevents slipping. It is difficult to judge of the merits of these articles from mere theorizing, but if it becomes necessary to use them, it will be well to examine various specimens that have been in use for years. If a new form is under consideration, it can, of course, only be judged from theoretical standards.

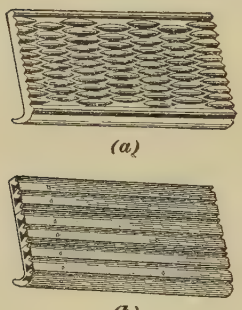


FIG. 136

A good form of tread that has been used is one formed of a sort of grille of cast iron *a*, Fig. 137, with square openings about $1\frac{1}{4}$ inches by $1\frac{1}{4}$ inches; into these openings are forced hardwood plugs *b* with the grain running vertically; the upper surface of the plug projects about $\frac{1}{4}$ to $\frac{1}{2}$ inch above the metal. A section of that tread is given in Fig. 137. The only part with which the foot comes in contact is the end grain of the square wooden plugs, which have spaces between them about $\frac{1}{4}$ inch wide. This is a real non-slip tread, though it wears more quickly than steel; it is easily renewable.

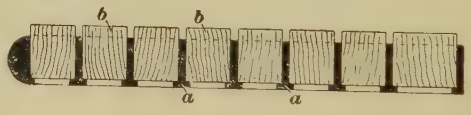
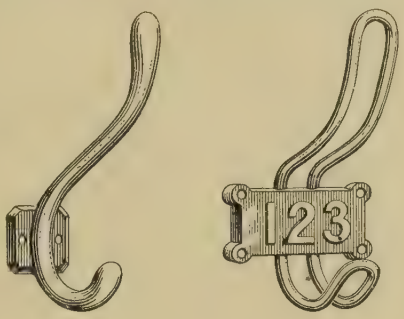


FIG. 137

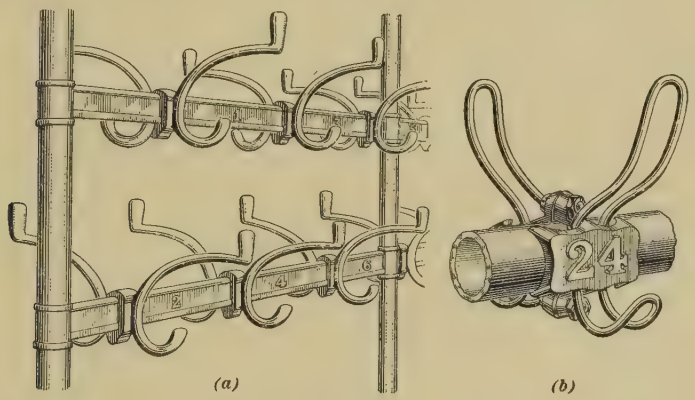
152. Hat and Coat Hooks.—The usual form of hat and coat hook used in houses is made of cast iron or cast brass, and

is of the form shown in Fig. 138 (*a*); they are fixed by being screwed to a wooden rail, which in turn is fixed to plugs in the wall. The disadvantage of hooks of this kind is that they are rather brittle, so for public buildings, and especially school work, a form of wrought-iron hook, as shown at (*b*), is generally used where they are to be fixed to wooden rails. For school work, where a large number are to be fixed, the method shown in Fig. 139 is generally adopted. At (*a*), the hooks formed in pairs are clipped over an iron bar and fastened at the bottom. At (*b*)



(*a*) (*b*)

Fig. 138



(*a*) (*b*)

Fig. 139

a similar arrangement is shown, but fixed to a round tube, two screws being necessary to each pair of hooks.

PLASTERING

GENERAL CONSIDERATION

USE

1. **Definition.**—The word plastering is used to denote any process by which various parts of a building are coated with a plastic material that ultimately becomes hard. This coating forms a surface that is more suited to the requirements of the building or more pleasing in appearance than the naked structure; it also serves as a ground for decoration. The process may also be used as an essential factor in the formation of parts of the building. This process is applicable to both the exterior and the interior of the structure. When used for exterior work, as in overlaying an inferior quality of stone or brick, or in forming the covering material or wall sheathing to protect the framework, it is classified either as *stucco work* or *rough cast.*

2. **Scope for Application.**—Improved processes in the manufacture of brick and terra-cotta, increased facilities for handling and cutting stone, and the desire for truthful construction have all acted to drive stucco work out of the field. So strongly has this reaction influenced the public mind that the term stucco has become identified with everything that partakes of a spurious construction and fraudulent concealment. This change in public taste has largely limited the exercise of the plasterer's art to interior work. In this restricted sphere, however, there is ample opportunity for the exercise of good, honest, and skilful work, as no other substance has yet been produced that so well

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satisfies the requirements in the treatment of the large areas that occur in interiors.

3. The natural march of progress, and especially the introduction of modern fire-resisting construction, has led to the development of new methods and the improvement of old ones, so that at present the art of plastering has reached a high degree of perfection, to obtain which the prime requisites are good material and good workmanship. In recent years, too, a form of plastering the exterior wall surfaces of buildings, known as rough cast, has become very popular and been largely used for domestic work in country and suburban districts. The architect should therefore be well acquainted with the nature and qualities of the materials and the proper methods of performing the work, in order to be able to write specifications intelligently and to see that they are properly carried out.

BASES FOR PLASTERING

4. As plastering consists in coating the surfaces of walls and ceilings with thin layers of a plastic material, the surface to be covered should present every facility for the perfect adhesion and retention of the material that is to be applied. Generally speaking, there are only two kinds of bases that are coated with plaster and built up with subsequent layers to form a mass of sufficient thickness to withstand pressure and to retain a true and uniform surface; one of these may be called a **lithic, or stone, base,** and the other, a **grille base.** In the first case, the plaster is laid directly on the face of the naked wall, which may be of stone, brick, or concrete; in the second case, it is spread over a grille-like arrangement of wooden or metal strips, the edges of which are sufficiently separated to allow plaster to pass between them and fold over on the inner face, thus forming a **key,** or continuous clinch, that will hold the plaster in position.

5. Lithic Base.—The key for plastering on brick or stone walls is generally obtained by leaving the mortar joints rough and projecting, or else by raking out the joints to a depth of about $\frac{3}{4}$ inch from the surface. With some kinds of brick,

stone, and concrete, on account of the hardness and smoothness of the surface, it is necessary to hack over the surface to obtain the roughness necessary to afford a key for the plaster. Some bricks that are much used for interior walling, but which have a surface that does not afford a good key for plastering, are moulded with a fluted or channelled face which gives the required key.

6. **Grille Base.—Lathing** is the general term applied to the grille base, and usually consists of wood in non-fire-resisting buildings like ordinary dwellings, and metal in fire-resisting structures. Although not absolutely necessary on brick and stone walls, as plaster adheres well to such surfaces, lathing is sometimes applied to exterior walls built of masonry. By this means the plaster slabs are isolated from the wall, and a clear air space intervenes. This arrangement ensures a continually dry surface, which would otherwise be liable to dampness from the condensation of the heated air of the room on the cold surface of the walls, or from moisture penetrating the body of the wall during a period of wet weather ; on the other hand, the space so formed may provide a refuge for vermin.

7. The laths for brick or stone walls are sometimes attached to vertical strips, 2 inches wide by 1 inch thick, called **battens,** which have been fixed to the walls by the carpenter ; these strips are set at 12- or 16-inch centres. For partitions the laths are attached directly to the studs, or vertical posts, that form the framing of the partitions. The laths for ceilings may be nailed directly to the under edges of the joists, or they may be attached to **counterlathing,** a series of strips, similar to those used on the walls, arranged at right angles to the joists and fixed at 12-inch centres. Better results are obtained by the latter method, as the warping of the joists does not so much affect the laths. If counterlathing is not executed, the laths would be fixed direct to the under side of the joists, and, consequently, no plaster would be able to squeeze up between them, to form a key, where they crossed the joists. For this reason, in good work the laths on ceilings are kept away from the wide face of the joists by narrow battens, or counterlaths, so that the amount of plaster not having a proper key may be reduced to a minimum.

MATERIALS USED BY PLASTERERS

LATHS

WOODEN LATHING

8. Material.—Though oak has been used, **laths** are now generally made of pine or spruce. They may be split or sawn, but split laths, generally called **riven,** are the better, as there are no cross-grained fibres to reduce their strength. Only riven laths should be used for holding the plastering. Sawn laths may be used for the first layer in counterlathing or brandering. The cross-grained fibres in sawn laths make them liable to warp and curl on account of the absorption of moisture from plaster. To avoid warping, all laths should be straight-grained; to ensure durability, they should be well seasoned and free from any appearance of sap, rot, or incipient decay; for strength, they should be clear of shakes and large or loose knots; and to prevent the subsequent discoloration of the plaster, the laths should be free from live knots and resinous pockets.

Laths vary in length from 2 to 5 feet, and in thickness from $\frac{1}{8}$ to $\frac{1}{2}$ inch. Their usual size is 1 inch wide, $\frac{1}{4}$ inch thick, and from 3 to 4 feet long, the length depending on the spacing of the battens, studs, and joists, in order to prevent waste of material. Laths are made in three thicknesses: those $\frac{1}{8}$ to $\frac{3}{16}$ inch thick are known as *single laths;* those averaging $\frac{1}{4}$ inch are *lath and half;* and those $\frac{3}{8}$ to $\frac{1}{2}$ inch are *double laths.* They are sold in bundles of 360 linear feet, which will cover $4\frac{1}{2}$ yards superficial and will require 500 nails.

9. Fixing.—Laths are fixed in parallel rows, the edges being kept fully $\frac{1}{4}$ inch apart, so as to enable the soft plaster to be pressed through and form a key. The ends of the laths should

be butt-jointed and flush. Continuous joints should not occur on one support, but the lathed surface should be divided into panels from 15 to 18 inches in width and the joints made to occur on alternate supports, as shown at *a c* and *b d*, Fig. 8, otherwise continuous cracks in the plaster will be liable to form. Laths are usually attached to joists and studs with cut or wire nails, about $1\frac{1}{8}$ inches in length and having large flat heads, one nail being used at each support. Work is made more solid by using two nails at each support, and in either case it is safer that two nails should be used in each end of every lath. The nails should be galvanized, to prevent moisture from rusting them, which would cause large yellow patches to appear on the surface of the plaster. In very good work zinc nails are used. Where Keene's cement and plasters of similar composition are applied, copper nails must be used, as these plasters contain ingredients that will make iron nails rust rapidly.

Where joists or studs are over 2 inches in width, a strip should be attached to them, so as to keep the laths clear of the wide surface and enable the plaster to form a key. Nails are sometimes thickly studded over wide surfaces of wood, such as beams, the plaster key being formed round the heads of the nails; but it is preferable to nail to the beam two layers of laths at right angles to one another. The practice of closing angles and narrow spaces with laths placed vertically should not be allowed, as an imperfect key is formed by the weight of the plaster, causing a downward flow of its substance.

METAL LATHING

10. Advantages.—Steel in the form of wire netting and of expanded and perforated metal laths has come into extensive use for the support of plastering, especially in fire-resisting structures. Plaster becomes more firmly attached to metal than to wood and is not loosened by ordinary accidents; and as the steel is embedded in the plaster, the plaster protects it effectively from fire, whereas wooden laths are only partially covered. Apart from fire-resisting qualities, metal laths are valuable in wood construction from the fact that plaster laid on

them will not crack or fall off should shrinkage occur in the woodwork. If the laths are set away from the joists and studs, these timbers will not show through the plaster, as is generally the case when plaster is laid on wooden laths. The objection has been raised that both wire and expanded-metal lathing require much more plaster than wooden lathing. In this fact lies their great value, for, as the mortar is the fire-resisting material, the lathing should be completely embedded in it; otherwise, the metal is perhaps of no greater value than wooden lathing. Numerous severe tests, both experimental and in actual fires, have demonstrated that plaster, especially the hard kinds, applied to metal lathing will successfully protect woodwork from fire if the wood is completely covered with it. Metal laths may be had either plain, painted, or galvanized. The last form, while more expensive, is preferable, as it is much stiffer and less liable to rust than the plain kind. Painted laths are nearly as good as the galvanized, and cost considerably less.

11. Blocking Pieces.—Wire lathing and plaster used to protect woodwork should not be in contact with the latter, but should be separated at least $\frac{1}{4}$ inch, while more space is advantageous. To secure this space, blocking pieces are necessary. These pieces may be either woven into the wire mesh or be separate pieces fastened to the wood before the lathing is applied. In the latter case, the strips may consist of corrugated or flat iron of proper width to give the required air space when set on edge, usually about $\frac{1}{2}$ or $\frac{3}{4}$ inch, and are fastened to the wood by small staples. The strips generally run lengthwise of the floor joists and studding; if laid crosswise, they will not have such a firm bearing, and should either be placed closer together or heavier strips should be used.

A substitute for this kind of blocking is made of $\frac{1}{8}$-inch rods spaced from 6 to 8 inches apart. These rods are kept away from the wood by separators made of small pieces of thin metal having the ends turned up from $\frac{1}{2}$ to 1 inch at right angles to the back, which is slotted to permit the insertion of staples. These blocking pieces should run across the joists, or studs, and the rods may be placed as close together as required.

12. Stiffened Wire Laths. — The use of separate blocking pieces forms an item of expense that may be avoided by substituting wire laths having ribs attached or woven into the mesh for plain wire laths. The laths with attached ribs consist of narrow strips of corrugated steel fastened to the netting at 8-inch intervals, crosswise to the length of the roll, by means of metal clips. The laths are nailed to the floor joists or studs with the strips next to the wood. The laths with woven ribs are formed of wire mesh having **V**-shaped stiffeners woven into the mesh at distances of about 8 inches. These ribs are made of sheet iron, and vary from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inches in depth, the former being more usual. The larger sizes are used for furring exterior walls, to provide greater air space. The wire netting is made with $2\frac{1}{2} \times 2\frac{1}{2}$, 3×3, and 3×5 meshes per square inch, the first being the usual size for lime-and-hair mortar, and the others being used with hard plasters. In Fig. 1 is shown a lathing of this kind; *a* represents the plaster; *b*, the wire, stiffened by the strips *c*, which are attached to the woodwork *d* by sharp pointed nails driven through the point of the **V**. Lathing of this kind is much used in America.

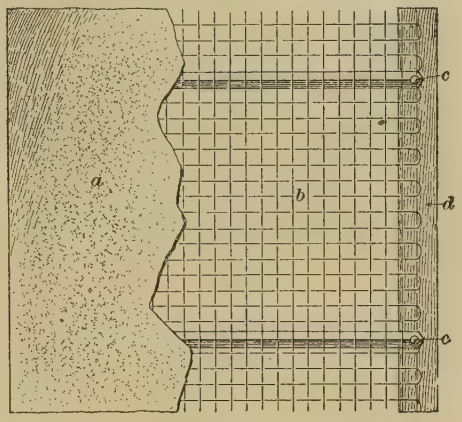

FIG. 1

13. Expanded-Metal Lathing.—Fig. 2 shows **expanded-metal lathing** that is made from thin sheets of soft tough steel. The sheets are first slit and then expanded so that a diamond-shaped mesh is formed, the width of the strips being turned nearly square to the surface of the sheet. This lathing may be had in various sizes of meshes, $\frac{3}{16}$ inch by $1\frac{1}{4}$ inches being commonly used. The standard sizes of sheets are 6 feet by 2 feet, 7 feet by

2 feet, or 8 feet by 2 feet 3 inches ; other sizes may be obtained if required. The thickness of the lathing is barely $\frac{1}{4}$ inch. This lathing possesses considerable stiffness and does not need stretching; it can be fastened directly to the floor joists and studding, but when laid on boards, metal furring should be interposed. The lathing is stiffer when placed so as to have the long diagonals of the mesh at right angles to the studding, to which it is fastened by 1-inch staples.

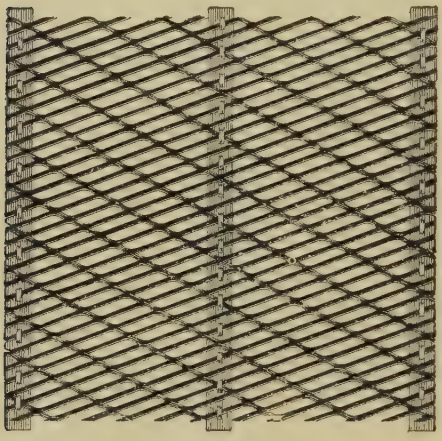

FIG. 2

14. Perforated sheet-metal lathing is made by corrugating, or ribbing, sheets of thin steel or iron and punching out, or expanding, some of the metal between the ribs, in order to afford a good key for the plastering. There are many kinds, but the general appearance of all is similar to that shown in Fig. 3. A usual size of the sheets is 8 feet long by from 16 to 24 inches wide. This lathing is much easier to put on than wire netting, and can be applied as quickly as wooden laths, being especially easy to bend to fit corners, where the laths should never be cut, but continued to the next stud beyond the angle, so as to stiffen the wall and prevent cracks at the corners. The lathing is fastened by means of barbed nails. The nailing

FIG. 3

should be started at the middle of the sheets and continued to the ends, in order to make them set firmly on the woodwork.

15. Metal Lathing in Wood Construction.—While metal lathing is preferable to wooden for ordinary structures, the additional cost generally precludes its use; but even in such buildings, there are many places where metal lathing may be of considerable advantage, while the increased expense is not very great. For example, cracks at corners of ceilings and partition walls can be largely prevented by bending a strip of wire netting, or lath, to fit the angle, and nailing it to the joists or studs on either side. Another place where metal lathing should be used is at the junction of a wooden partition and a brick wall, when there is no battening on the wall and especially when the partition is flush with it. If a strip of metal lathing is lapped 12 inches on both wall and partition, cracks at the junction will be avoided. When plaster is applied to exterior brick walls having wooden lintels, difficulty is sometimes experienced from the plaster cracking at the joint or not sticking to the wood. To obviate this, the joint should be covered with a strip of metal lathing fastened to both brickwork and lintel. The foregoing uses are only a few of the numerous valuable applications of metal lathing to wood construction; others will doubtless suggest themselves.

PLASTERING MATERIALS

INGREDIENTS

16. Up to quite a recent period, practically all interior plastering was composed of lime, sand, and hair. When plaster is made of a good quality of lime that is well slaked and properly mixed with the other constituents, it is very durable; but much of the lime plaster now used is made of inferior materials, so that much of it is practically valueless so far as durability is concerned. The substances that enter into the composition of the plaster will depend on the nature of the surface to be coated, the order in which the layer is applied, and on the desired finish. For

ordinary work, these are *lime, water, sand, hair,* and *plaster of Paris.*

17. Lime.—Many limes that make good mortar for other purposes are unfit for use in plaster, as they contain more or less overburnt hard lumps that resist the action of the water and fail to readily disintegrate. Eventually, these overburnt particles will slake, or what plasterers call *blow,* and cause small pieces of plaster to fly off. Walls and ceilings may sometimes be seen pitted all over from such action. In many places, a number of brands of lime may be had, and, unless the slaking qualities are known, care should be exercised in selecting one for plastering purposes. In any case, the best practice is not to use lime until it has been slaked at least a week, as even with the best limes considerable time is required for the slaking of all the particles.

18. In order to ensure thorough slaking, the fresh lime as it comes on to the site should be slaked with a sufficient quantity of water in a barrel. From this barrel it should be passed through a sieve as a creamy liquid into a box or pit, where it should remain for at least 3 weeks before being used. All that will not pass through the sieve should be thrown away and should not be used. Remaining wet in this box will cause all the particles to slake if it is not taken out too soon. This box now contains pure slaked lime, which should be taken as required to make up the various mixtures used by the plasterers.

19. Lime is sold unslaked by the ton in bags containing 2 or 3 bushels each ; it may be had either ground or in lumps. Hair is sold in bags by the hundredweight ; sand by the cubic yard. Stone lime is put into bags containing 2 bushels and lias lime in 3-bushel bags ; 16 bushels of stone lime equals 1 cubic yard ; 30 bushels of lias lime, or 32 of stone lime, equals 1 ton ; 100 tons of lias lime yields $59\frac{1}{2}$ tons of quicklime, 1,583 bushels of ground lime, and 2,063 bushels of slaked lime.

20. Sand.—Sand for making plaster should be angular, of medium fineness, and free from loamy matter or clay. Before using, all sand should be well screened, to remove the coarse

particles, and if wanted for hard finish, it should be sifted. The best plaster is made of sand that is screened, washed, and dried. In most cases, the sand is merely screened river or pit sand; the river sand, though possibly cleaner, does not as a rule make such strong mortar as pit sand, because the grains are water-worn smooth and rounded, not angular and sharp. Sand must be washed if necessary. There are the same objections to using sea sand for plaster as for other mortar.

21. Hair and Fibre.—Hair and fibre are used in plaster for the reason that ordinary lime mortar does not possess sufficient cohesive power to bind it together firmly. Hair is used almost exclusively for this purpose, but experiments have been conducted in America with a view to ascertaining the efficiency of Manila fibre as a substitute, with satisfactory results. Sawdust has also been used for the same purposes. Cattle hides are the chief source from which plastering hair is obtained. After being cleaned from grease, the hair is washed and dried and then packed into bags. The hair of salted hides is undesirable, owing to the presence of salt, which is not easily extracted. Goat hair is often preferred to ox hair in America. The hair should be well beaten out with a lath before use, to prevent its remaining in lumps.

22. Plaster of Paris.—Plaster of Paris is obtained by the heating of a crystalline mineral called *gypsum*, which is classified as a hydrated sulphate of lime, its constituents being water, salts of sulphuric acid, and lime. Extensive deposits of this stone exist near Paris, France, from which fact the trade name is derived. The chief value of this plaster is that paste made from it sets rapidly and within a few hours acquires its full strength. Plaster of Paris is very soluble in water, which renders it unfit for external use; but it is invaluable for cornice mouldings and enrichments, and is also used in several plastic mixtures. Its volume expands slightly in setting, and on this account it is a good material for filling chinks and holes in repair work. Plaster of Paris is much used for making casts, etc., which are generally moulded hollow, owing to its liability to crack when formed into pieces of any considerable thickness. When plaster

of Paris is mixed with lime mortar, in which case the lime mortar is said to be *gauged*, the setting takes considerably less time than that of pure lime mortar.

MIXING AND MIXTURES

23. **Hand Mixing.**—Except in a few large towns the great bulk of plaster is mixed by hand, and for the best results requires very close regulation of materials and careful manipulation. The mixing should be performed as much as possible outside of the building to be plastered, so as not to make the interior damp from the vapour of slaking lime. When plaster is mixed in cold weather, it should be done under shelter, and in no case should frozen plaster be used. A good quality of lime having been selected, it is slaked with clean water in a tight box, and run off as a liquid paste, as previously described, into a box or pit, and allowed to stand for about 3 weeks, if possible, before use. By using this paste as the base, the various coats may be made by adding other materials. The mixtures are generally classified as *coarse stuff*, *fine stuff*, *plasterer's putty*, and *gauged stuff*.

24. **Machine Mixing.**—The advantages of machine-mixed plaster over plaster mixed by hand are that sufficient time is given for the lime to thoroughly slake, the hair and sand are added just before use, and the mixing is performed much more uniformly. Briefly, the process is as follows: Fresh lime is placed in revolving pans, enough water being added to slake the lime slowly. When this process is completed, the lime and water are run through screens and pumped into tanks, and allowed to remain there for about 3 weeks in order to finish slaking. When plaster is to be made, the paste is run into mixing pans, where hair and sand are added and the mass is thoroughly stirred until it is entirely homogeneous.

25. **Mixtures.**—**Coarse stuff** is composed of lime and sand in the proportion of 1 part of lime to 2 or 3 parts of sand. In this mixture, long ox hair is incorporated to the extent of 1 pound of

hair to every 3 cubic feet of stuff. Coarse stuff is mixed up in large quantities and left in a heap, from which it is taken as required. **Fine stuff** consists of lime taken from the box as a stiff paste and mixed with a small quantity of fine sand in about the proportion of 3 parts of lime to 1 part of sand. **Plasterer's putty** is similar to fine stuff, but the lime has been passed through a finer sieve. **Gauged stuff** consists of plasterer's putty and plaster of Paris in the proportion of 3 or 4 parts of putty to 1 part of plaster of Paris. It sets rapidly and should be mixed in small quantities as required.

SPECIAL PLASTERS

26. General Description.—Several chemical or patent plasters are to be had, possessing characteristics which render them specially suitable for particular purposes. The constituents and methods of manufacture are not in all cases publicly known, but they consist for the most part of gypsum prepared in different ways and with different admixtures. What is, as a rule, claimed for these plasters is that they are harder than lime plaster, quicker in setting, more fire resisting, and more durable. Of the better-known and more widely used varieties, *Parian*, *Keene's*, and *Martin's* should be mentioned. These plasters set very quickly and can be papered or painted a day or two after they are finished. They are very hard, and in ordinary three-coat plaster work it is often specified that the angles be formed of one of these on a Portland cement backing. They must not, however, be used for outside work. Other special plasters, such as *Sirapite* and *Granite plaster*, are obtained from their respective manufacturers with instructions as to their use, which should be carefully followed.

27. Parian Cement.—**Parian cement** is manufactured by mixing calcined and powdered gypsum (plaster of Paris) with borax, then recalcining and grinding. For ceiling work the first and floating coats should be of Parian and sand in the proportion of 1 part of Parian plaster to 2 parts of sand with 1 pound of hair to 3 cubic feet of plaster. On walls the under coat is formed

of 1 part of Portland cement and 3 parts of sand. The finish is of neat Parian. If the surface is to be painted, the plaster must not be backed by Portland cement on account of the efflorescence. There are two qualities of Parian, coarse and superfine.

28. Keene's Cement.—**Keene's cement** is formed by compounding plaster of Paris with alum. It is used in much the same way as Parian, and is to be had in three qualities, coarse, fine, and superfine. The last is perfectly white and capable of taking a high polish.

29. Martin's Cement.—**Martin's cement** also is made of plaster of Paris and carbonate of potash. It is made in three qualities, coarse, fine, and superfine.

30. Sirapite.—**Sirapite** is a patent plaster which sets with great rapidity and a hard surface, so that it is unnecessary to form the angles in Parian or Keene's. It is used in two coats and is in some places cheaper than the ordinary three-coat work. It may be worked up to a polished surface. It is said to be the best plaster for use on reinforced-concrete work.

31. Granite Plaster.—**Granite plaster** is a patent quick-setting hard plaster formed from gypsum. It is also used with expanded metal lathing in forming a thin solid partition of considerable strength.

32. Selenitic Lime.—**Selenitic lime** is formed from some hydraulic lime by the addition of plaster of Paris or other sulphate. The effect of the sulphate is to arrest the slaking action, quicken the setting, and strengthen the lime. For plastering purposes, this lime is first mixed with water to a creamy consistency, then sand is added in the proportion of 1 part of lime to 3, 4, or 5 parts of sand. It works better if mixed with a small amount of ordinary lime putty.

33. Advantages of Hard Plasters. — Hard plasters have many points of superiority over lime plaster which more than balance their extra cost and which will in time probably result in their almost exclusive use. Being machine-mixed, the plaster

made from them is uniform in quality and strength and has unvarying proportions of the constituents, while two batches of lime plaster may differ a great deal in this respect. They are also much harder and more tenacious, and resist fire and water better than lime, and the small quantity of water used in mixing enables them to dry much more rapidly. They are not injured by frost after they have begun to set, but should be protected from it for the first 36 hours after being put on the walls. Heat and moisture are not readily transmitted by hard plasters, and being more dense than lime plaster, they neither absorb noxious gases nor permit the entrance of disease germs.

PLASTER SLABS AND PARTITIONS

FIBROUS PLASTER

34. Fibrous plaster slabs are made of some fibrous material, generally rough canvas on a framework of laths, embedded in plaster of Paris, and are used chiefly as a substitute for lathing and the first coat of plastering, one face of the slab being grooved, or rough, to make the plaster adhere well. The usual size of each piece is from $\frac{5}{8}$ to 1 inch thick, 2 feet 6 inches wide, and 4 feet long. Fibrous plaster slabs can be readily sawn and nailed, and may be put up very rapidly. They are fastened directly to the studs, furring, or joists. They are very nearly as fire-resisting as terra-cotta tile, and on account of their lightness and the ease of setting them are sometimes used for suspended ceilings, partitions, etc. As lathing and the first coat of plaster, and often the second coat, are not required when these slabs are employed, the saving, taken in connection with their low cost, makes them a very cheap, yet effective, kind of fire-resisting construction. The slabs may also be had with a smooth finished surface, in which case they are nailed up with spaces about $\frac{1}{4}$ inch wide between them, these spaces being afterwards filled in with plaster. When used for fixing to ceilings or soffits, these fibrous plaster slabs can be obtained reinforced with wire netting, so as to avoid as far as possible any danger of the material falling.

PLASTER PARTITIONS

35. Several forms of partition now in use are composed of plaster or some similar material, with or without metal or wire lathing. The three principal types are the *reinforced fibrous plaster slabs*, *patent slab partitions*, and *metal lath and plaster partitions*.

36. **Reinforced fibrous plaster slabs** are slabs similar to those just described, only having a wire reinforcement to hold the plaster. They are also made with a backing of slag wool, when

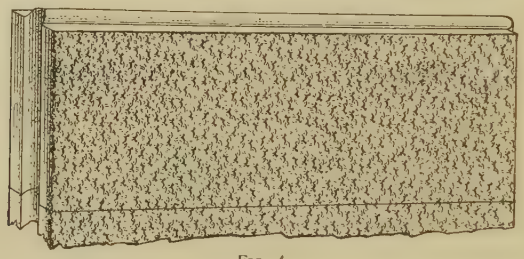

FIG. 4

they may be used as facings to an ordinary stud-partition to form a fire-resisting and sound-resisting partition.

37. **Patent Slab Partitions.**—Various forms of partition now on

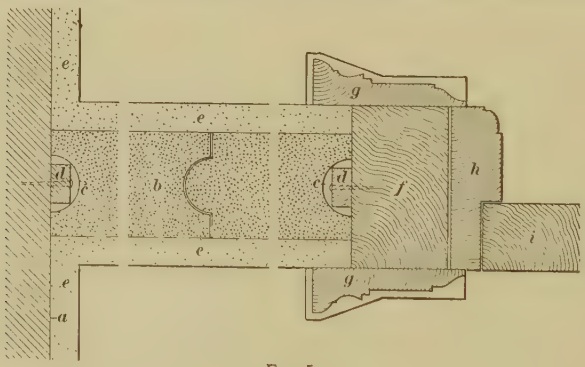

FIG. 5

the market are composed of slabs from 4 feet to 6 feet long and 1 foot deep, composed of plaster with reeds embedded therein or

of some light form of concrete, such as breeze and cement or breeze and plaster of Paris. They are made either with a keyed joint for greater strength, as in Fig. 4, or with a straight joint. Their surfaces are finished like the fibrous plaster slabs to receive either one or two coats of plaster or with a smooth finished surface ; they are made from $1\frac{1}{2}$ to 4 inches thick. Fig. 5 shows a method of fixing the partition to a wall and of fixing a door

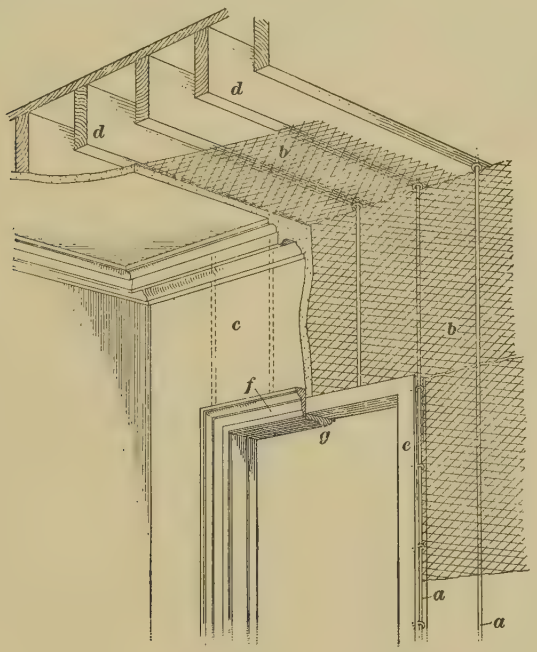

Fig. 6

frame in the partition. At *a* is shown the surface of brick wall ; at *b*, the slab partition ; at *c*, *c*, grooves in the end of the slabs to contain the wooden fillets *d* nailed to the brickwork or the back of the door frame, as the case may be, to form a key to aid in steadying the partition ; *e* is the plaster ; *f*, the door frame ; *g*, the architrave ; *h*, the lining ; and *i*, the door.

38. Metal Lathing and Plaster Partitions.—The metal lathing and plaster partitions consist of some form of metal lathing fixed,

as may be necessary for stiffness, to small steel rods. This is then plastered on both sides, generally with some special hard plaster. These partitions are very thin and occupy little space and yet are strong. Fig. 6 shows such a partition partly plastered : At *a*, *a* are the stiffening rods, which are 12 to 15 inches apart, carefully fixed between the wood joists of the floors ; *b* is the metal lathing ; *c*, the plaster; *d*, floor joists of the floor over ; *e*, the door frame, having one of the vertical stiffening rods *a* fastened to the back of it by means of galvanized-iron staples or nails ; *f* is the architrave covering the joint between the plaster and the door frame, and *g* is the rebated lining to which the door is hung.

TOOLS

39. The implements used by the plasterer are simple and inexpensive ; the principal ones are shown in Fig. 7. At (*a*) is shown an ordinary **screen**, which is used for separating the coarser particles of sand and gravel from the finer ones. At (*b*) is shown a screen through which the slaked lime is passed to free it from gritty or unslaked particles ; for very fine division, small wire and hair sieves are sometimes employed. The **box** in which the lime is placed after slaking is a platform of rough boards battened on the bottom and having sides 10 or 12 inches high, making a water-tight box, in which the slaked lime is left for several weeks and from which it is taken as required to be mixed up with the sand and hair. The **larry** (*c*) and the **shovel** (*d*) are used for mixing the materials. The **hawk** (*e*) is a piece of board about 10 inches square, provided with a short handle. It is used to hold small quantities of prepared plaster, or stuff, ready for applying with a trowel. The ordinary **laying-on trowel** (*f*) is used for applying plaster to the walls ; it is a thin plate of polished steel, about 10 inches long and $4\frac{1}{2}$ inches wide, having a wooden handle. Various other forms of trowel, for gauging, pointing, etc., varying in length from 3 to 7 inches, are shown at (*g*), (*h*), and (*i*).

40. **Floats** are used for smoothing, or floating, the surface of the second coat. At (*j*) is shown the **hand float**, which is merely

a piece of board with a handle on the back ; it is usually made of pine, but for producing the finished surface of very fine work, a cork face is sometimes used. For rough finish, the surface of the float is often covered with carpet, etc. A two-handled float, called the **derby,** is shown at (*k*) ; this is a straightedged piece of wood, usually from 3 to 6 feet long, and is used for floating larger surfaces than can be readily worked with a one-handled float. It is not used in London, and only in some places in the country. The straightedge is more generally used instead. The **straightedge** (*l*) is a long piece of smooth board, having its under edge planed straight and true. It is used for the walls and ceilings, in order to obtain plane surfaces. The **square** (*m*) is used for testing the trueness of angles. The **plumb** (*n*) is used to determine the perpendicularity of the surfaces by applying one of its straight sides to the surface. If the plumb-line, hanging freely, lies along a shallow groove cut into the face, parallel to the sides, the edges are true. **Jointing** and **mitreing tools** (*o*) and (*p*) are used for picking out and finishing angles and mitres in mouldings, etc. The **scratch** (*q*) is used for scratching the surfaces of the first and second coats of plaster, to form a good key for the ensuing coat ; it consists merely of pieces of laths nailed together, and having one end sharpened, as shown. A coarse broom or bundles of twigs may be used instead.

41. Brushes of various kinds are used by the plasterer. That shown at (*r*) is used for dampening the surface of the plaster while it is being worked smooth. **Templates** of various kinds are used for forming cornices and mouldings. The templates are made of zinc cut to the required outline, and are backed by wood. At (*s*) is shown one form of template, which consists of a board *a*, to the bevelled inner edge of which is attached a thin zinc or steel plate cut to the outline of the cornice, as at *b*. The strip *c* and handle *h* brace the board *a* firmly and keep it square with the wall ; *f g* represents a guide strip on which the strip *c* slides, and *d e* a line drawn on the ceiling flush with the outer edge of the board *a*, which is always kept along this line. A plasterer's hammer for lathing and general work is shown at (*t*) ; one end is in the form of a hatchet blade with a slot *a* for extracting nails.

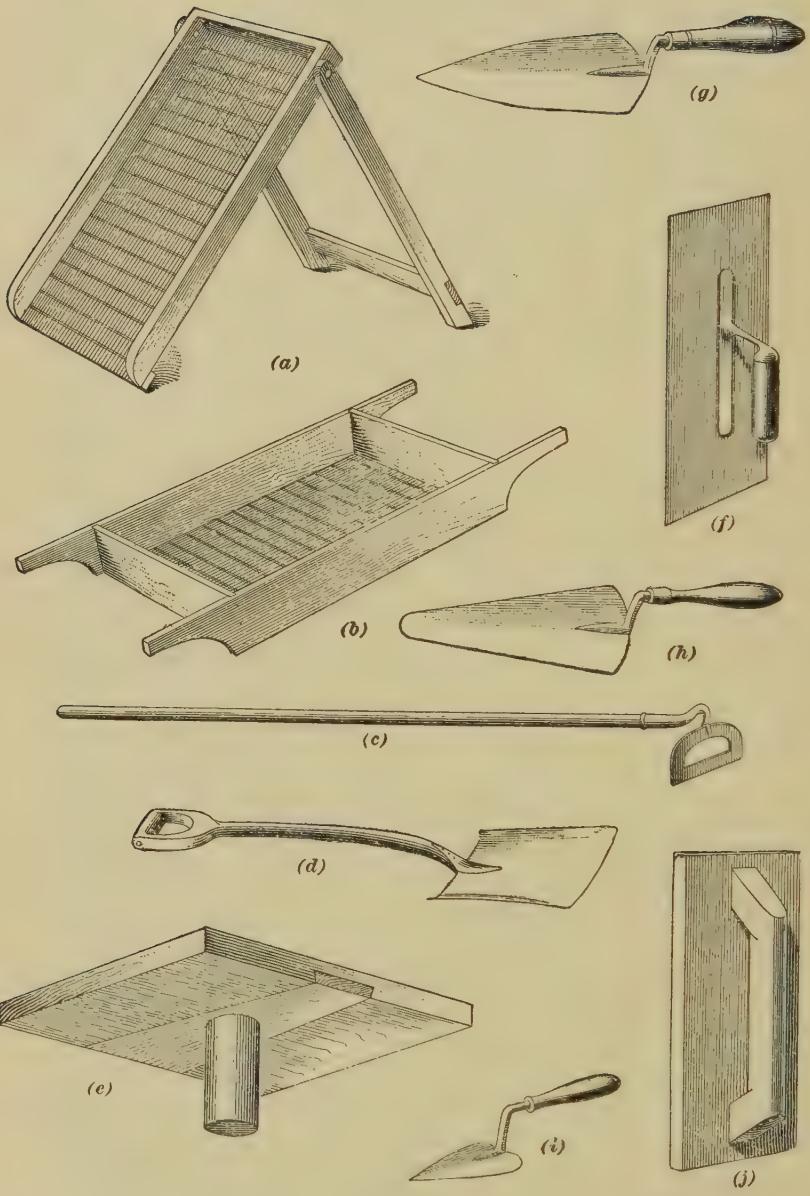

FIG. 7

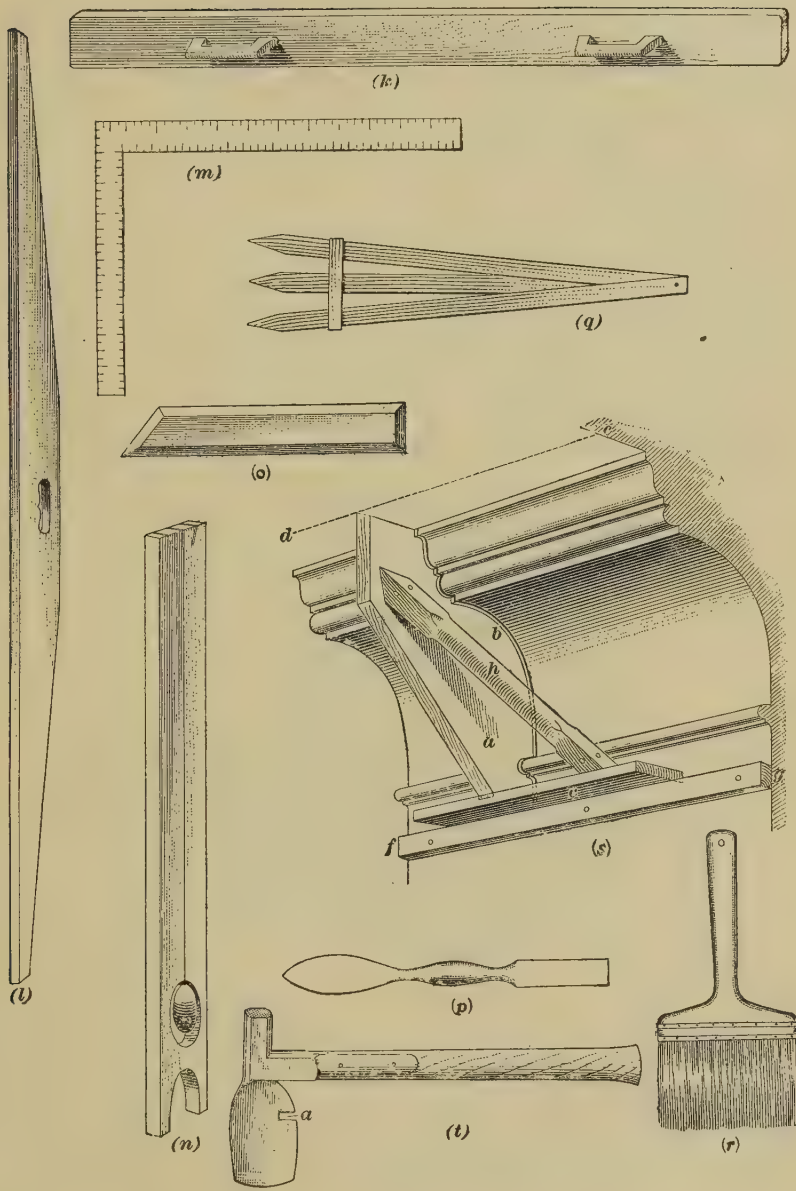

FIG. 7

APPLYING THE PLASTER

PLANE SURFACES

42. Preliminary Examination.—The carpenter's specifications require all surfaces to be properly prepared for lath and plaster, and that suitable plaster grounds (plaster grounds are rough wood fillets fixed behind joinery to finish the plaster against and fix the joinery to), such as shown at *e*, Fig. 8, be affixed to the brickwork and framework for the future attachment of

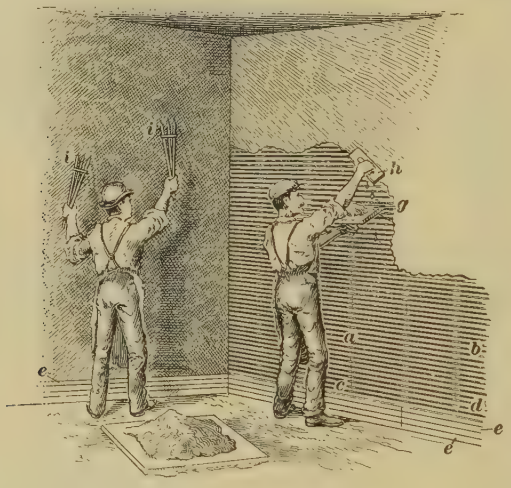

FIG. 8

the finished joinery. But the plasterer should test the alinement of the walls and ceilings, or he may find that considerable building-up is necessary when he comes to apply the second, or floating, coat. Where this is necessary, the lathing should be stripped off, and the surfaces brought to a plane by the use of furring fillets. In the case of dished, or concave, surfaces on

stone or brick walls, the deficiency should be made good with cement mortar before the first coat of plaster is applied. This course will ensure a more durable wall, as there is little value in a mass of lime mortar unless it is applied in thin layers and thoroughly compacted.

43. Particular attention should be given to the spacing of the lathing. Although a simple matter in theory, in practice it will be found that unless much care has been taken in spacing the strips, many narrow insignificant slivers have been used for closers; these should be discarded and the panel stripped and relathed, otherwise much of the strength of the wall will be lost. For three-coat work, which is most generally used, the plaster grounds on brick or stone walls that are to be coated on a solid wall should be $\frac{3}{4}$ inch in thickness, and those for lathed surfaces $\frac{7}{8}$ inch. At no point should the surface of the solid wall or that of the lathing approach the face of the grounds nearer than the regulation thickness for the plaster, which will be about $\frac{5}{8}$ to $\frac{3}{4}$ inch. The face of the stone or brick walls is more or less irregular, and grounds less than $\frac{5}{8}$ inch in thickness are of little value for attaching the finished woodwork.

44. Names of Coats.—Plaster for internal work is usually applied in three coats, although in some localities two is the customary number, the first coat being straightened and smoothed carefully to receive the finishing coat. This, however, is done in the cheaper kinds of plastering only. The first layer applied is called *rendering* or *pricking up;* the second, the *floating;* and the third, the *setting*. Three-coat plaster work is specified as *render, float,* and *set,* when applied to walling or other surfaces where no lathing is needed; where lathing is used it is described as *plaster, float,* and *set.*

45. Rendering Coat.—The method of applying the first coat is illustrated in Fig. 8. The coarse stuff is taken in batches from the heap, tempered with clean water to the proper degree of firmness, shovelled into hods, and carried to the rooms and deposited on the mortar boards, shown on the floor, ready for

application by the plasterers. A quantity of plaster is placed on the wooden hand board, or hawk, *g*, by means of the trowel *h*. Slices of the plaster are then cut from the hawk and spread firmly and evenly over the surface of the lathing or the naked wall, as the case may be. The plaster should have a dough-like consistency, should be tough and hold well together, and should be soft enough to be readily pressed in between the laths, so that it will bulge out behind and form the key. The thickness of the layer should be fully $\frac{1}{2}$ inch, so that when set it will furnish a rigid surface to work over. After the coat has somewhat hardened, which requires from 2 to 4 days after application, it is scratched over diagonally with the combs *i*. The scratches, or grooves, thus formed in the plaster fulfil the same function as the spaces between the laths: to allow a good key for the subsequent layers. The first coat should be nearly dry before the next is put on; if too dry, the surface should be slightly dampened with a sprinkler or brush before the second coat is applied. If plastering is applied directly to brick or stone, the joints in the latter should be raked out, so as to form a better key for the plaster. The walls should also be free from dust and slightly damp before the plaster is put on.

46. Floating Coat.—The second coat, which consists of fine stuff to which a little hair is sometimes added, is applied from $\frac{1}{4}$ to $\frac{3}{8}$ inch thick when the first coat has become sufficiently firm to resist pressure. The second layer is called the **floating coat,** because its surface is worked by means of the floats; all the wall surfaces are straightened and made true by its application. On walls, if the grounds are set true and the surfaces are not too large, the plastering can usually be brought to a true plane without much difficulty. On the ceilings, however, there is nothing to guide the plasterer, and in many cases, if great care is not taken, the ceilings have a rolling surface, as may be seen at the edges.

47. In order to get perfectly even walls and ceilings, especially in cases where the grounds are insufficient, resort is had to what is known as *screeding*. **Screeds** are plaster bands 5 or 6 inches in width formed on the surface to be floated. The surfaces

adjacent to the angles are carefully plumbed up from the plaster grounds *e*, Fig. 9, but are kept back about $\frac{1}{8}$ inch from the face, to allow for the finishing coat; vertical screeds *f* are formed by means of the straightedge *g*. Similar screeds *h* are formed along the ceiling angles; these screeds are made straight, and kept in the same plane as those at the angles. Intermediate horizontal or vertical screeds *i*, *j* are then formed between the screeds adjacent to the ceiling and the plaster grounds, as preferred by the plasterer. These are usually placed from 4 to 8 feet apart, and are gauged to line by means of the straightedge. The screeds thus form a system of framing that has been reduced to a true plane. The panels may then be filled in flush, in line with the screeds, and firmly rubbed down with the two-handled float, or derby, *k*, or with a straightedge. The surface is then worked over with a wooden hand float, the coat being firmly compacted by incessant rubbing; should the coat become dry during the process, it is moistened by applying water with a wide brush. A close, firm layer can be obtained only by the thorough laborious operation of pressing and rubbing the particles of the mortar together; and herein lies the secret of strong, durable work: plenty of elbow grease. In order to form a rough base for the subsequent coat, the surface is scratched over with a broom. The ceiling surfaces are treated in a similar manner, and the screeds are carefully levelled so as to obtain true and level planes. The space between the plaster grounds and the floor is usually finished with a rough rendering of plaster, so as to prevent air-currents from entering the room through the spaces between the grounds for fixing the skirting.

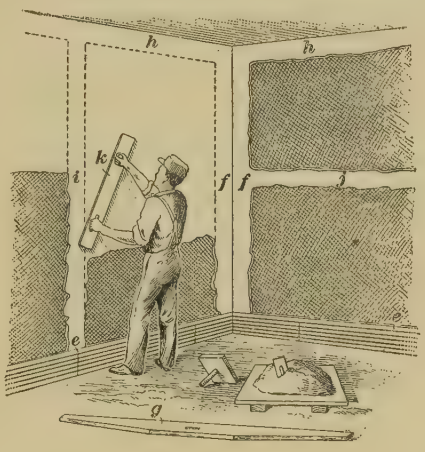

FIG. 9

48. **Green Work.**—**Green work** is the name given to work which has been recently laid and has had insufficient time to set. Sometimes the second coat is put on while the first is still green. In such a case the first coat is made very rich, while the second coat contains a large proportion of sand and is worked into the first so as to really form only one coat. While it saves time, this practice cannot be commended. A much better plan is to allow the pricking-up coat to dry before the floating coat is put on, although more labour and lime are thus required. Another objection to putting a second coat on while the first is green is that the excess of moisture causes the laths to swell badly, which, in drying, shrink and produce cracks in the plastering.

49. **Setting Coat.**—Where the wall is to be papered, the finishing coat of plaster should be composed of fine stuff with sand and a little hair; if the surface is to be whitened or coloured, the last coat should be of plasterer's putty and sand. If it is desired that the coat should set quickly, gauged stuff may be used. The material is applied to the wall in the form of a stiff paste by means of the steel trowel *a*, as shown in Fig. 10, and is spread uniformly over the surface to a thickness of about $\frac{1}{8}$ inch. To obtain the best finish and uniformity of surface, the workman often keeps the surface moist by passing a brush *b* over it at the same time he is using the trowel *a'*.

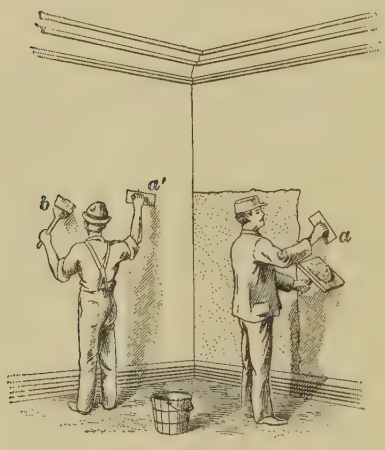

FIG. 10

50. **Quantities of Material.**—For 100 yards superficial of plastering the rendering coat will require 1 cubic yard of lime, 2 cubic yards of sand, 16 pounds of hair. Three coats, render, float, and set with fine stuff, will require $2\frac{1}{3}$ yards of lime, $2\frac{1}{3}$ yards

of sand, and 30 pounds of hair. Three-coat work on laths, lath plaster, float, and set, will require $2\frac{1}{2}$ yards of lime, $2\frac{1}{2}$ yards of sand, 32 pounds of hair, 22 bundles of laths, and 14 pounds of nails.

MOULDINGS

51. Cornices.—As a rule, cornices are moulded before the finishing coat is put on, the operation of making them being about as follows: Longitudinal strips *b*, *b*, Fig. 11, are first attached to the wall, on which a template *a* is run. Sometimes a strip is also attached to the ceiling, but more often the ceiling guide is merely a line. The template with the true profile of the cornice is placed

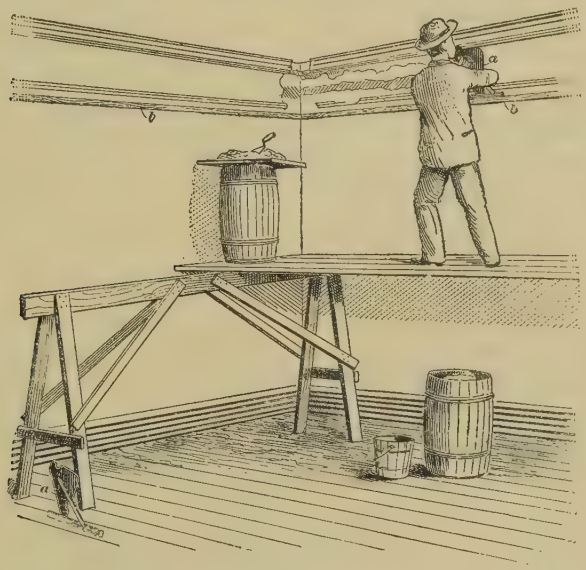

Fig. 11

in position and moved along the guides with one hand while the plasterer applies the material to the wall with the other. Fine stuff is thrown on to form the rough body of the cornice and gauged stuff is applied to form the face, the plasterer having some of each material at hand. Another method is to first run the cornice with a *muffled template*, which will give the cornice

a form a little within the true finished form ; then the moulding is run with the true template, which permits a thin coating of gauged stuff to be applied to the approximate form left from the muffled template and gives the cornice its finished form. The internal and external angles cannot be finished by means of the templates, but must be carefully moulded and mitred by hand, using jointing tools, such as shown in Fig. 7. Some plasterers prefer to push the template with the left hand instead of with the right, as shown in the figure, so that they can handle the trowel with the right hand when applying the stuff and make up any deficiency ; therefore, the templates should be made to suit the direction in which they are intended to be driven.

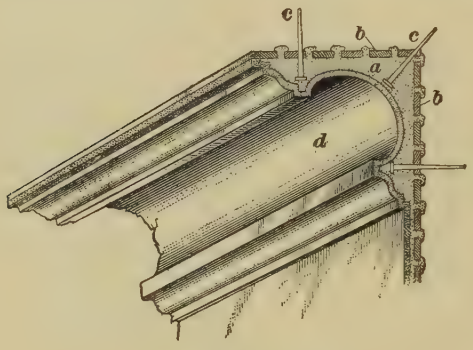

Fig. 12

52. Sometimes the key is reinforced and the plaster held more firmly in place by using projecting spikes or large nails, which are driven into the wall or ceiling before the plaster is applied. This method is shown in Fig. 12, in which *a* shows the plaster; *b*, *b*, the laths; *c*, *c*, the spikes; and *d*, the finished surface. When the cornice projects considerably, the angle should be blocked, or cradled, and lathed, to reduce the quantity of plaster required, as there should be no thickness of plaster much over 2 inches. This method is represented in Fig. 13, in which *a*

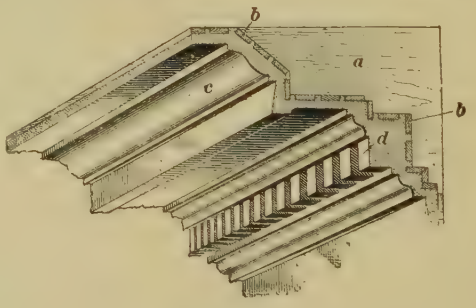

Fig. 13

shows one of the blocks, which are nailed to the floor joists ; *b*, *b*, the laths ; *c*, the cornice ; and *d*, a dentil course. If the cornice is to be ornamented as at *d*, a recess is left in the plastering to receive the pieces to be inserted, which are formed separately and then stuck in place by liquid plaster. When there is much ornament, it is cheaper to cast the cornice in plaster of Paris, in sections 2 feet or more long ; these may be attached to the wall by thin plaster. Careful work is required to make the moulded pieces come together or match properly.

53. Centrepieces.—Centrepieces that consist only of plain circular mouldings are formed in the same manner as cornices, except that the mould, or template, is so fastened as to swing round the centre of the ornament. When decorated centrepieces are used, they are usually cast in a mould and stuck on the ceilings with plaster of Paris. Nearly all kinds of ornamental plastering, such as panelled ceilings, bas-reliefs, imitations of foliage, etc., may be easily cast in plaster of Paris and made to serve the purpose as well as more costly decorations.

EXTERNAL PLASTER WORK

54. Stucco.—The term stucco was first used by the early Italian artificers to define a superior grade of plaster compounded by them, and their skilful manipulation of the material has never been excelled. From the fact that by using stucco the appearance of dignity and stateliness on an otherwise mean and poverty-stricken structure could be acquired at a very low cost, it was for many centuries very extensively used. Many of the so-called stone and marble palaces will be found, on examination, to be only brick shells coated or veneered with stucco, but so well treated and handled as to present a very superior surface, being scarcely discernible from the material that it is made to imitate. At the present time, stucco is used only to a limited extent and only for a cheap class of structures. The word stucco is now generally used as a kind of generic term for all kinds of external plaster work with a smooth finish. It was much in vogue in the early part of the 19th century,

but there is now a certain stigma connected with the use of the word.

55. To secure the best results in stucco work, a good cement mortar is requisite, as lime mortar, which was formerly used, does not prove very durable. For use on brickwork, the plaster should be made of Portland cement and clean sharp sand mixed in the proportion of 1 part of cement to 3 parts of sand, with sufficient water to make a stiff paste. Before adding the water, the mortar joints in the brickwork should be raked out, so as to form a good key for the covering, and the surface of the wall should be well dampened to prevent the bricks from too quickly absorbing the water in the mortar. Resort is sometimes had to screeding, to make the surface true and uniform. When the plaster is put on in more than one layer, the previously laid coat should not be allowed to dry before the next one is applied, as the coats will not adhere well and will probably scale off. Before the finishing coat has hardened, it may be marked with lines to indicate the joints in ashlar; but this is a reprehensible practice. The plaster may be coloured to represent stone by the use of mineral colours, such as Venetian red or the ochres; while if a light colour is desired, it may be obtained by mixing a small quantity of lime with the cement. Stucco is sometimes divided into classes or kinds, such as *common stucco*, *rough stucco*, *trowelled stucco*, and *bastard stucco*. These differ from one another slightly in composition and finish.

56. **Rough Cast.**—Rough cast has been much used in recent years for domestic buildings in country or suburban districts. It is, as its name implies, a plaster finish having a rough surface which is sometimes obtained by throwing washed pebbles or shingle on to the moist plaster; from this it obtains the name of *pebble dashing*. Rough cast should be laid in two coats formed of lime or cement and coarse sand and clean gravel in the proportion of 1 part of lime to 3 parts of sand. The first coat should contain hair, as in plasterers' coarse stuff. The exact composition and manner of application differs according to the taste of the architect, but the final coat is generally thrown on from the trowel and left without being smoothed over by a float.

Colouring matter, generally ochre, may be introduced into the material, provided it is not in too large a quantity. If cement is used for the finishing coat, the colour is disagreeable and distemper is often applied. One hundred yards superficial of two-coat rough cast requires about 20 bushels of lime, 2 yards of sand, 16 pounds of hair, and $\frac{3}{4}$ yard of gravel.

57. Sgraffito.—Sgraffito is an Italian word used to denote a kind of ornamented plaster work in which the ornamental design is scratched on the surface of the plaster while it is wet. It may be done by applying two coats of plaster of different colours, subsequently cutting away parts of the outer coat in the form of the design so as to expose the lower coat. Sgraffito may be applied internally or externally, but it is not much used in this country, though in Italy work of this kind has been carried to a high degree of perfection.

INSPECTION OF WORK

58. Lathing. — Before the lathing is begun, the foreman should see that the battens and grounds are properly placed and are plumb and square ; also, that the angles of chimneys and other projections are right angles. If the lathing is of wood, he should see that the laths are free from bark and loose knots, and that they are put on with proper spacing, well nailed, with no springy ends, and end joints broken at least every 18 inches. Over door and window openings the laths should extend to the next stud on either side of the frame. As far as possible, the lathing should run the same way, as cracks are liable to occur in the plastering at places where the direction of the lathing is changed. The junction of brick and wooden walls, as well as lintels and timbers without counterlathing, should be covered with pieces of metal lathing.

59. Plastering.—If lime plaster is to be used, the foreman should see that the lime is fresh and without unburnt lumps, and should allow none to be used that has begun to slake. The sand used should be sharp and free from earthy matter. The hair should not be added until the lime has become thoroughly

slaked and cooled, and the plaster should be made at least a week before it is used. It is well to become acquainted with the appearance of good plaster, so as to be able to judge its quality. Before beginning to plaster, the openings in the building should be closed with boards or muslin. In winter, a building in which plastering is to be done should be heated. Lime mortar especially is rendered worthless if frozen and then thawed; hard plasters, also, should not be permitted to freeze. The foreman should see that the first coat is well keyed between the laths, and is thoroughly dry before the second coat is put on. If the pricking-up coat is to be laid on bricks, the walls should be well wetted before the plaster is applied. Special care should be taken with the floating coat, as the appearance of the finished work depends to a great extent on good workmanship in applying this coat. Its surfaces should be plane, with straight and square angles and a level ceiling. If hard plasters are used and the material is not obtained already mixed for use, the directions furnished by the makers in regard to mixing, sand, etc., should be carefully followed. Plaster that has partially set before use should be rejected.

GLASS AND GLAZING

GLASS

MANUFACTURE AND USES

PLAIN GLASS

1. **Glass.**—All glass is composed of three chemical elements, namely, silica, soda, and some metallic oxide. These are mixed in varying proportions to suit the requirements of each case, and sometimes receive some additional element to vary the colour or degree of transparency of the finished product. The principal properties upon which the value and utility of different kinds of glass depend are : transparency, fusibility, and viscosity at a red heat, whereby it may be moulded into any desired form. It is not necessary to know the exact nature of the constituents of all the different forms of glass, but a knowledge of the methods of manufacture will be of great assistance in determining the kind and quality of glass upon inspection, or in deciding upon the precise kind best suited to some particular purpose.

There are three general varieties of glass used in architectural work, namely, **crown glass, sheet glass,** and **plate glass,** each used under certain conditions, limited by the character of the work and the details of the manufacture of the glass.

2. **Crown glass,** now seldom used, is made by dipping the end of a long iron tube, called a blowpipe, into the melting pot, and collecting thereon a lump of semi-fluid glass, which is then, by blowing through the tube, extended into a large hollow

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globe, as shown in Fig. 1. The mass is then transferred to an iron rod, called a **puntil,** and is heated while it is rotated rapidly and, under the influence of the centrifugal force of rotation, spreads out into a large flat disc, called a *table.* This naturally causes the glass to become gradually thinner toward the edge, while at the centre, where it was attached to the rotating rod, is a large boss, or bulb. In cutting the glass into panes, this boss, or **bullion,** as it is called, was formerly regarded as waste and was cut out and thrown into the waste pile to be remelted with the next charge in the pot. Now, however, these bullions are sought after for the glazing of windows in imitation of old examples. The remainder of the table will, under favourable circumstances, make about 13 square feet of window glass, but if cut in large-size panes, only 10 or 11 square feet can be secured. The largest regular panes of crown glass are 18 inches by 12 inches, and the largest available panes about 33 inches by 25 inches. These large panes, however, are so warped or curled, owing to the original globular shape from which they are formed, that they must be flattened before being put on the market for use. This flattening is accomplished by heating the glass to a red heat and letting it lie on flat slabs to cool. The smaller sizes do not usually require flattening, the amount of curl in them being so slight as to be scarcely noticeable.

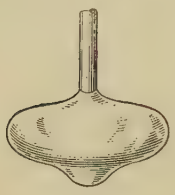

Fig. 1

Crown glass is put on the market in two thicknesses, the thinner brand, called **ordinary,** being about $\frac{1}{20}$ inch thick and weighing 10 ounces per square foot, while the **extra** or heavier quality is about $\frac{1}{16}$ inch in thickness and weighs from 12 to 15 ounces per square foot. These qualities are packed in crates, the contents of which vary in amount, according to the thickness and form of the glass. A crate of ordinary quality should contain 18 tables, while a crate of *extra* usually contains 12 tables, or, of course, a larger number of panes, depending on the size of the latter. The available length of these panes varies with the width, but no single sheet can be obtained of greater area than 5 square feet. Crown glass is classified in five qualities, only three of which are used for general building purposes. These

are best, used for first-class work ; seconds, used for cheap work ; and thirds, which are of little use except for inferior situations.

FIG. 2

FIG. 3

FIG. 4

Crown glass is more transparent than either of the other varieties, but the fact that it is available only in small panes so limits its use that sheet glass has superseded it for general building purposes.

3. Sheet glass is gathered and blown similarly to crown glass, except that after the globe is formed, it is rolled in a moulding block and the blowing is continued until the glass takes the form of a long hollow cylinder, as shown in Fig. 2. The end of this cylinder is then reheated and opened as shown in Fig. 3, while the

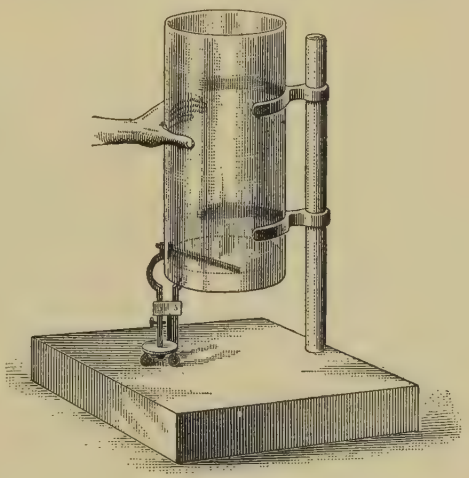

FIG. 5

cylinder is rapidly revolved until the edges flare out and extend the sides to the edge, which is then cut off while the glass is still hot, the cylinder then assuming the form shown in Fig. 4. The cylinder is allowed to cool and is then detached from the blowpipe, by placing a hot wire or bent rod round its upper end, as shown at *a*, the wire being held by the loop *b*. The edges are then made parallel and true, by placing the cylinder in the trimming machine illustrated in Fig. 5. This consists of a pair of clamps on a perpendicular rod, against which the cylinder is held with one hand, while a moving diamond is passed round the bottom, cutting off the glass perfectly even and straight. The cylinder is then transferred to the splitting block shown in Fig. 6,

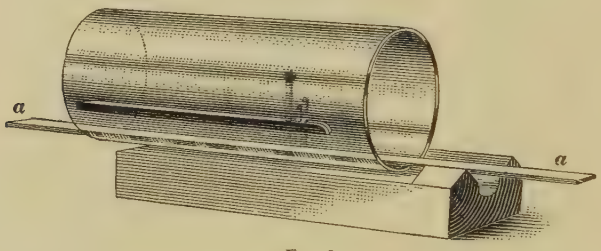

Fig. 6

where another diamond moving in a horizontal guide *a a*, cuts the cylinder down one side parallel with the axis. It is now transferred to a flattening kiln, where, under the influence of heat, it gradually opens out and unrolls until it becomes a flat sheet of glass. When cooled sufficiently to handle, it is cut in panes and packed for shipment. Sheet glass is used for building purposes in four qualities, namely, **best, seconds, thirds,** and **fourths.** The last mentioned, being a very common quality, is used only for inferior situations, such as cottages and workshops. Sheet glass is available in much larger sizes than crown glass, and in six thicknesses, from $\frac{1}{14}$ inch to $\frac{1}{5}$ inch; it varies in weight from 15 ounces to 42 ounces per square foot. Every $\frac{1}{16}$ inch in thickness adds 13 ounces to the weight per square foot.

4. The largest sizes available in sheet glass are shown in Table I.

These sizes are governed by the maximum area of the blown cylinder. A sheet may be of the maximum length or the maximum breadth as shown in Table I, but no combination of length and breadth can be obtained which will exceed the area given in

TABLE I

SHEET GLASS

Weight Ounces Per Superficial Foot	Thickness Inch	Maximum Length Inches	Maximum Width Inches	Maximum Area Square Feet
15	$\frac{1}{14}$	60	38	15
21	$\frac{1}{10}$	80	50	26
26	$\frac{1}{8}$	80	50	25
32	$\frac{1}{7}$	75	48	20
36	$\frac{1}{6}$	70	44	17
42	$\frac{1}{5}$	60	40	15

the last column, and any size larger than 50 inches by 36 inches is subject to a special price above the regular market quotations. Sheet glass is sold in crates, the contents of which vary according to the thickness of the glass.

Sheet glass has, as before stated, very largely superseded crown glass for window glazing on account of its availability in larger openings. Besides this advantage, however, it is comparatively free from the wavy undulations prevalent in crown glass, and recent improvements in its manufacture leave little difference in its relative transparency. Selected sheet glass is sometimes polished on both sides as described hereafter, and when so treated is called **patent plate,** or **blown plate,** to distinguish it from the ordinary polished plate described below.

5. Plate glass is manufactured by a process totally different from that of either of the varieties already described, the essential difference being that it is cast and not blown to the required form. For this reason plate glass is always much thicker than blown glass, and until polished lacks the transparency obtained by the other methods. Inferior grades are likely to contain air

bubbles and other imperfections, but the superior varieties are completely free from imperfections and do not distort or deform objects as do crown and sheet glass. The three principal varieties of plate glass, termed respectively **rough-cast plate, rough-rolled plate,** and **polished plate,** are distinguished by different surfaces, formed in the process of casting or by subsequent grinding and polishing.

6. Rough-Cast Plate Glass.—In the manufacture of rough-cast plate glass the melted glass is poured on to a long cast-iron table, over which a heavy iron roller is passed by means of cog wheels. The glass is thus squeezed out before the advancing roller and pressed into a sheet, the size of which is limited only by the length of the table and the width of the roller. The thickness of the sheet is regulated by strips of metal laid along each side of the table, on which the roller bears and by which the width of the sheet is regulated. After the rolled plate is cool enough to be removed from the casting table, it is carried to the annealing oven and there permitted to remain for several days. In the annealing oven, under the influence of a high temperature, it softens, becomes more homogeneous in composition, and less likely to crack or break under subsequent changes of temperature. The sheets or plates, when removed from the annealing oven, are not smooth and transparent like the finished products of blown glass, but have an irregular, rough, undulating surface, and are used for skylights, floor lights, and in situations requiring a glass which is non-transparent but diffuses light well.

7. Rough-Rolled Plate Glass.—**Rough-rolled plate glass** is manufactured in a manner similar to plate glass, but the surface of the casting table is covered with a series of fine corrugations about $\frac{1}{16}$ inch apart, or with flutes, which mark one side of the glass correspondingly, the other side being smooth. The glass is rolled in thicknesses of $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 inch, in sheets up to 30 feet in area, and is used for situations requiring a coarse, strong, non-transparent glass which will diffuse light well.

8. Polished Plate Glass.—Polished plate glass is made in a manner similar to rough-cast plate glass, but with more care

and from superior material, the cast and rolled plate being carefully ground to a perfectly plain surface, smoothed, and polished on both sides. It is sold in thicknesses of $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, and 1 inch, the area of the sheets varying from 25 feet to 280 feet, the latter being exceptional.

9. Polishing Glass.—When the plates are withdrawn from the annealing oven, they are carefully examined for any defects, such as air bubbles, opaque spots, etc., and those plates which are free from imperfections are selected and set aside for polishing. This is accomplished in three operations, namely, grinding, smoothing, and polishing. The grinding and smoothing table consists of a revolving slab, with a bar fixed horizontally, about 10 inches above its surface, to which two iron runners are attached. The glass to be ground is cemented to the table with plaster of Paris, and the runners are set to rest evenly on its surface. This apparatus is shown in Fig. 7. The slab or table is seen at *a*; the runners at *b* are pivoted at *e* to the fixed rod or bar *c d*, when the table is revolved by machinery. The runners are independently revolved on their bearings *e*, and being fed with emery or sharp sand and water, every part of the plate is evenly abrased and the surface is ground down until perfectly level and true. The smoothing process is conducted on the same table and in the same manner, but the runners are fed with a finer grade of emery, or, in place of the runners, two plates of glass are revolved on each other with fine flour emery between, by which means the surface of the glass is rendered perfectly smooth, but not transparent. When both sides of a plate are ground and smoothed, it is removed from the table

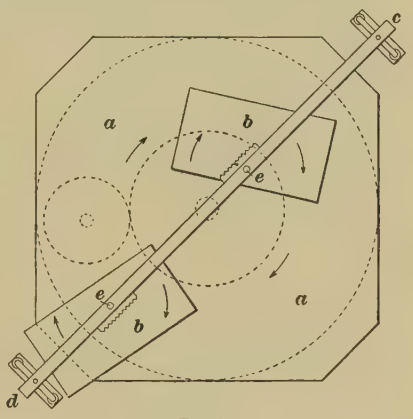

FIG. 7

and polished with felt rubbers, supplied with jewellers' rouge and water. This operation removes every trace of abrasion by the sand or emery, and leaves the plate perfectly clear and transparent, but about 40 per cent. less in thickness than when it left the annealing oven. The finest varieties of polished plate glass are termed *silvering* quality, and are reserved for mirrors.

10. Bevelled Plate Glass.—The term **bevelled plate** is applied to plate glass the edges of which are ground, smoothed, and polished to form a bevel, or a border which is not in the same plane as the general surface of the glass. This greatly enhances the appearance of a pane by giving a brilliant finish to the edges, and is performed upon one or both sides of the glass by means of a series of revolving discs of cast iron, stone, and willow wood.

11. Glass Bending.—The bending of glass for shop fronts, show cases, etc., is an operation frequently required, and is carried out on glass which has been finished and polished, by carefully heating the same in a special furnace until softened, after which it is gently bent on a special mould shaped to the desired curvature. The operation is one requiring great care, and is generally followed by a partial repolishing of the glass.

OBSCURED GLASS

12. Obscured Glass.—For situations in which glass is required to intercept the vision while still transmitting light, a great number of obscured glasses are to be obtained, in addition to the two forms of rough-cast plate and rough-rolled plate already referred to. These are made in sheet, or plate, glass, in an immense variety of surfaces and patterns.

13. Ground glass is manufactured by roughening the surface of ordinary glass with abrasives, which is now generally performed by what is called the sand-blast process.

14. Fluted, and corrugated, sheet glass, as the names imply, consist of sheet glass in which ribs are formed to obscure the definition of objects seen through the glass.

15. Muffled, or dappled, sheet glass is distinguished by an irregular wavy surface, formed by blowing the bubble of white or tinted glass into a mould, the surface of which is modelled with the desired pattern. After being removed from the mould the glass is reheated and stretched to a cylinder, being subsequently split and flattened as previously described.

16. Crystalline, or Chipped, Glass.—The glass illustrated in Fig. 8 is called **crystalline, or chipped, glass,** and is manufactured in the following manner: The glass is first given a coat of glue and is then placed in a heated receptacle; this process tends to contract and curl the glue, so that when it dislodges itself from the glass the cohesion will draw or chip off particles of glass, leaving the surface uneven and showing a design similar to that on a frosted window light. Chipped glass can be procured in either the single or the double process, that is, with a single or a double chipping; and these processes are adaptable to either sheet or plate glass, white or coloured.

FIG. 8

17. Figured rolled glass is plate glass which has been cast on a table furnished with a roller having an indented surface, which impresses the desired pattern on the surface of the glass. Figured rolled glass is made in a very great number of patterns, few of which may be considered artistic, but nearly all answering admirably the purpose of obscuring definition and transmitting and diffusing light well. **Rippled glass** is practically the rolled equivalent of muffled sheet glass previously described, the pattern, however, being more defined, and the effect, in consequence, more mechanical. Four varieties of figured rolled glass are illustrated in Fig. 9, representing, however, only a fractional proportion of the market patterns, obtainable in white and in some half-dozen tints.

18. A variety of figured rolled glass, known as the **Flemish pattern**, is in many respects superior to the above. It is charac-

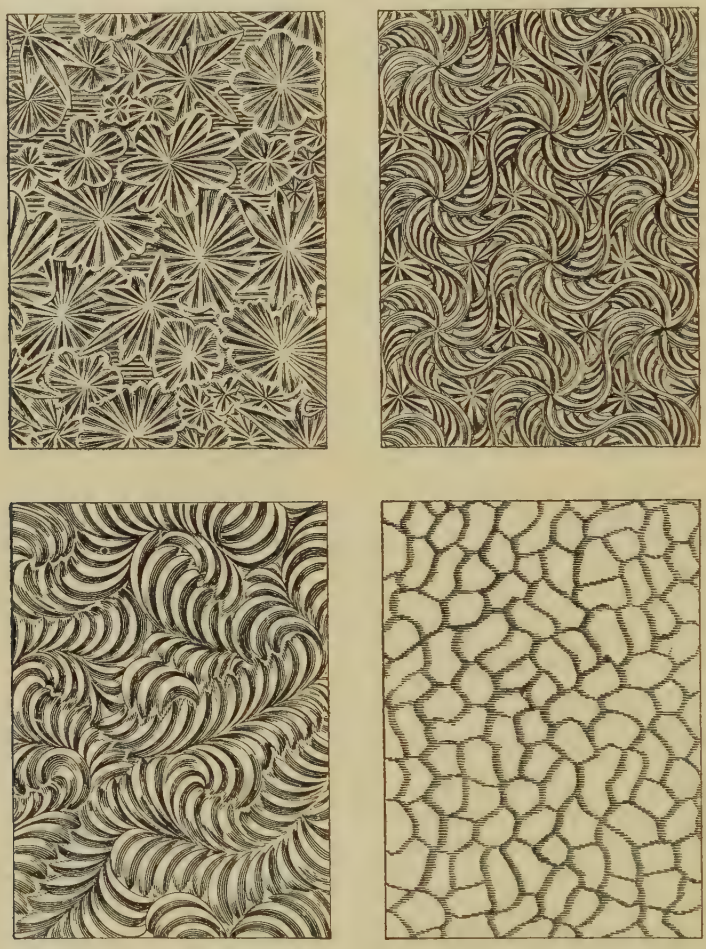

FIG. 9

terized by a slightly undulating surface on one side, and is applicable for work in which the strong mechanical marking of the patterns indicated in Fig. 9 would be unsuitable.

19. **Tinted Glass.**—Perhaps the most popular of the cheap tinted glasses are the varieties known as **cathedral tinted** and

cathedral rolled. The former is a sheet glass tinted in pale or negative colours, and was until recently in great request for the windows of churches. This glass, however, has been largely replaced by the unpolished tinted glass known as cathedral rolled, the double rolled cathedral glass having in turn supplanted, to a certain extent, the single rolled. Both are non-transparent, and have a wavy surface, and may be obtained in white as well as in a variety of tints. The usual thickness is $\frac{3}{8}$ inch, weighing about 26 ounces, but the glass may also be obtained in thicknesses of $\frac{3}{16}$ inch and $\frac{1}{4}$ inch. For important work the coloured glasses known as *antiques* are in every way to be preferred. The last mentioned, however, belong more properly to the province of the glass painter and a description of them will consequently be found in *Stained Glass.*

ORNAMENTAL GLASS

20. Ornamental Glass.—For situations requiring a moderately obscured glass of special texture or colour, with an effect superior to that of the figured or cathedral rolled, but with a corresponding increase in cost, a number of special glasses are available. Among these are ambitti sheet, slab, or bottle, glass, pressed slabs, and *antiques.*

21. Ambitti Sheet Glass.—The glass known as **ambitti** is produced by keeping the molten glass, or *metal*, as it is called, at a certain temperature for some time before blowing. This tends to crystallize the material, and produces a glass marked apparently by a fine *pitting*, to which the sparkle and character of this glass are due.

Stock sizes of ambitti sheet glass are about 40 inches by 30 inches, the usual thickness being rather less than $\frac{1}{8}$ inch, and weighing about 18 ounces per foot.

22. Slab, or Bottle, Glasses.—**Slab glass** is the name given to certain fine glasses which are produced in small size panes by a peculiar process. The metal is blown into an iron mould the interior of which shapes the glass into a square bottle resembling a Leclanché cell. The metal flows into the mould in varying

thicknesses, being about $\frac{1}{2}$ inch in substance in the centre of each side and the bottom, and thinning off rapidly toward the corners. These bottles, the best known of which are called **Norman slab bottles,** are made generally in seven sizes, ranging from $12\frac{1}{2}$ inches by $10\frac{1}{2}$ inches to $5\frac{1}{2}$ inches by $3\frac{1}{2}$ inches, and are split at the corners into five panes of glass. The process is utilized chiefly for producing panes of silvery-white glass or of rich-coloured glass, the tone of which varies with the thickness, being deeper in the middle than toward the edges. Owing to the small size of the panes, such glass is commonly united with lead bands, or *cames,* into what are known as leaded lights.

23. Pressed Slab Glass.—Glass of a somewhat similar character to the above is manufactured by stamping or pressing, and can be obtained in sizes slightly larger than the bottle slabs, squares of 8 inches being customary.

WIRED AND PRISM GLASS

24. Wired Glass.—Glass with wire embedded therein, as illustrated in Figs. 10 to 12, is made either obscured and rough rolled, or clear and polished. The wire netting is embedded in its centre during the process of manufacture, thus producing a very strong glass that is a good fire-retardant. The temperature at which the wire is embedded in the molten glass ensures cohesion between the metallic netting and the glass, and the two materials become as one. Consequently, if the glass is broken by shock, by intense heat, or from some other cause, it remains practically intact. Wired glass combines the strength of the wire netting and the glass plate, and the wire is so thoroughly covered as to obviate the possibility of rust or

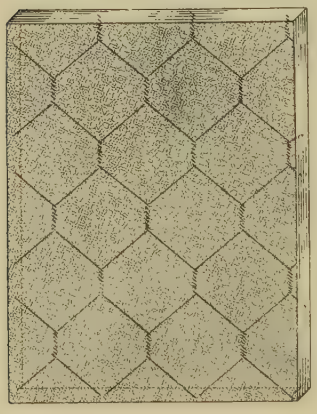

FIG. 10

corrosion. This glass possesses extraordinary strength, a piece $\frac{1}{4}$ inch thick being as strong as ordinary glass of twice that thickness. When wired glass is broken, it will not scatter like plate,

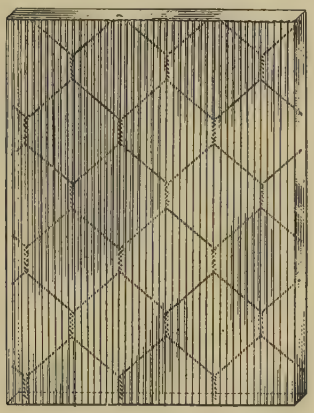

Fig. 11

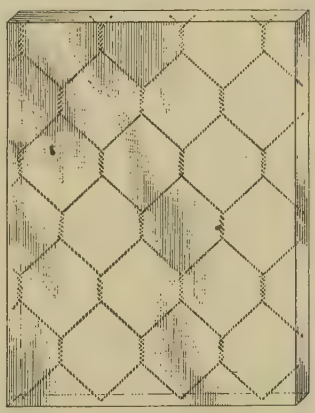

Fig. 12

or skylight, glass ; it is consequently extensively used for overhead work, where falling glass due to accidental breakage would be a source of danger.

25. Wired glass is made $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{7}{16}$ inch thick, and up to 40 inches wide and 120 inches long. It is practically burglar-proof and missile-proof, and when set in approved metallic frames forms a most efficient fire-retardant window. As a fire-stop, it possesses the advantage that it does not hide the incipient blaze, like steel-plate or metal-lined shutters. Windows glazed with wired glass require no shutters for protection, but, when necessity arises, an opening may be made in the glass by a blow from a fire-axe.

The behaviour of wired glass, under very trying conditions, was tested by the British Fire Prevention Committee in 1905. An official report subsequently issued showed that the glass withstood a temperature of 1,660° F. and the effects of a strong force of water at 45 pounds pressure turned on the red-hot metal. At no time during the test did flames or water pass through the glass. Careful examination of the latter, when cold, showed that the glass was starred all over, but no holes were discovered.

The experiments were regarded as conclusive proof of the value of wired glass when used in connection with windows, skylights, and other exterior openings exposed to fire risks. Clear-polished wired glass is also extensively used for museum and jewellers' show cases and for shop windows in which valuables are exposed.

26. Prisms, or Prismatic Glass.—When a ray of light passes from air to glass, it undergoes the change in direction called *refraction*. Knowledge of this property of light is utilized in the design of **prismatic glass**, an example of which is illustrated in Fig. 13. Prisms are made of clear crystal glass, with the outer side usually plain. The inner side, however, is formed into prisms of a great variety of angles made to suit the several conditions under which the lights may be used. Prism plates are made in two styles: *Pressed prism plates*, which consist of pressed lenses 4 or 5 inches square, glazed together with a cast-iron or copper bar, the copper bars forming the frame being brazed together electrically; and *rolled*, or *sheet, prisms*, which are first rolled in large sheets and then cut to size.

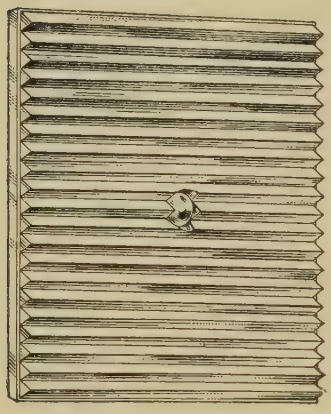

FIG. 13

27. Under average conditions, the direct light from the sky entering a room through sheet or plate glass strikes the floor within a few feet of the window and is mostly absorbed. For this reason, the rear part of the room is dark. By the installation of prisms at the window openings, however, the direction of the entering light is changed and projected horizontally into the room. Prisms do not create light; they simply distribute and diffuse the excess light at the window. Under certain conditions the effective light in a room may be increased fifty times by the installation of prisms. In Fig. 14, the arrows *a* show the direction of the lowest rays from the sky over the cornice of the opposite

building, striking the prism plate at the floors. These arrows also indicate vertical rays, striking canopies and skylights, while the arrows *b* show the directions of the rays just mentioned after passing through the prism plate, and also the manner in which the rays of light are projected into the building.

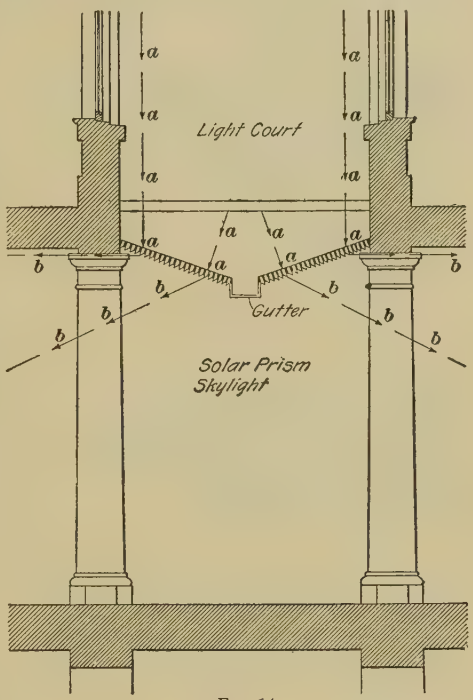

Fig. 14

28. Pavement Lights for Basement, or Cellar, Lighting. Where the pavement and the basement ceiling are nearly on a level, basement rooms can be lighted successfully by the installation of glass **pavement lights.** The ordinary method is to use plain, round, or square lenses, which are set in iron or concrete and iron frames, as illustrated in Figs. 15 and 16. Vault lights, however, are now made with the supporting material of reinforced concrete. Where the ceiling is low or the room at all deep, the system in which plain lenses are used is unsatisfactory, as the direct light from the sky in passing through the lens strikes the floor immediately underneath.

A more satisfactory method is to use double prism lenses set in the necessary frames. The upper prisms receive the direct light from the sky on the upper face and turn, or refract, it back into the basement, by means of the inner prisms, as illustrated in Fig. 17. Where the head-beam or other obstructions interfere with the deflection of light direct from the prism, it becomes

necessary to use in connection with the skylight or canopy just described an independent vertical frame of window prisms of

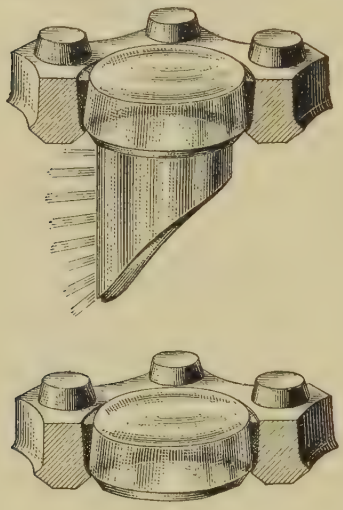

Fig. 15

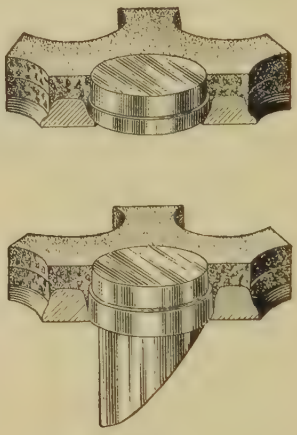

Fig. 16

varying angles. These prisms intercept the light from the pavement tiles and project it into the basement.

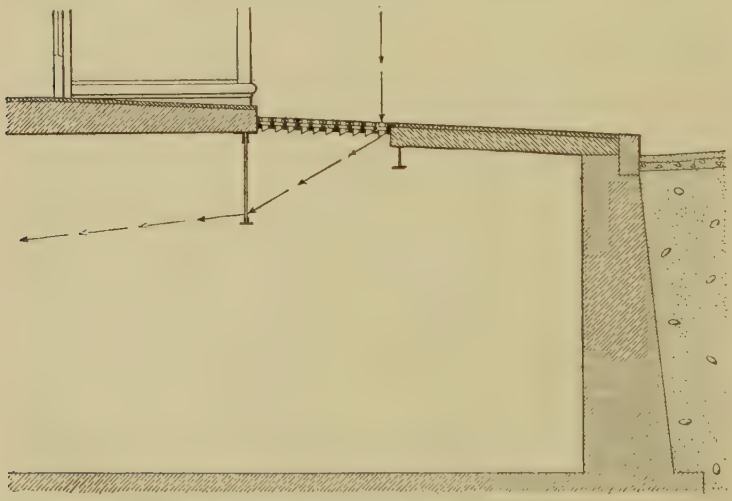

Fig. 17

GLAZING

FIXING WITH PUTTY

GLAZING WOOD AND IRON FRAMES

29. Glazing Into Wood.—The simplest form of glazing is into rebates formed in wood frames, the glass being held in position by means of putty, which is a composition of raw linseed oil and whitening, ground and kneaded into a stiff paste resembling dough. The glass should be slightly smaller in size than the extreme distances between the rebates, in order that the intervening bed of putty may obviate fracture owing to concussion. In such glazing the woodwork is first primed with white lead paint so that the putty will adhere, and the rebate is *back puttied*, that is, a layer of putty is spread over the rebates, and the glass is firmly bedded on the same, being nowhere in contact with the wood. The rebate is then filled with putty of triangular shape, with which the glass is held in position. The putty is layed and finished with a special knife called a *glazing knife*.

Large panes of glass are first secured by means of triangular pieces of zinc, called sprigs, driven at intervals into the sides of the rebates, before the front putty is applied. *Glaziers' sprigs*, which are small iron nails, resembling brads, but without heads, and square in section, may be used. The sprigs are nailed in position with a small hammer called a *bradding hammer*, as with this tool there is less likelihood of breaking the glass than with an ordinary hammer.

30. Glazing Into Iron.—This is performed in a similar manner to the foregoing, the putty being composed of linseed oil, whitening, and red lead: the sprigs, in this case, are short metal pegs driven into holes drilled for their reception.

FIXING WITHOUT PUTTY

ORDINARY METHOD

31. Glazing Into Wood.—In superior work putty is not used for securing the glass into woodwork, wooden beads or fillets being substituted. In the best class of work these beads are fixed to the frames by means of brass screws and cups, so that they may readily be removed when necessary. In order to make such glazing watertight when used for external situations, the beads should be bedded in red lead.

LEADED GLAZING

32. The practice of uniting, by means of lead, small pieces of glass into larger sheets, or *lights*, dates from very early times, when glass was obtainable only in small pieces and was expensive. For these reasons the sheet of glass was divided into small panes, or *quarries*, to obviate waste and reduce the cost of replacement if a pane were broken. In modern times the artistic value and appropriateness of leaded glazing for certain work have been recognized, and such glazing is exceedingly popular. The glass for transparent windows is usually sheet glass of light weight, generally that described as 15- or 21-ounce, which is cut into diamond, rectangular, or other shaped pieces and united with H-shaped bands of lead, called **cames**, which are soldered at the intersections.

An important point in connection with leaded lights is the nature and application of the cement with which the glass is bedded into the cames. This is made of whitening, plaster of Paris, boiled linseed oil, turpentine, red lead, litharge, and lamp black, mixed to the consistency of treacle and applied to the surface of the panel. It is then thoroughly worked into the joints with a stiff brush, care being taken that every portion is thoroughly flushed before cleaning off, or the work will not be air- and water-tight.

33. Lead Cames.—The lead cames for uniting the various pieces of glass are made in a variety of sections such as flat, round, beaded, etc., as shown in Fig. 18, at (*a*), (*b*), and (*c*), respectively, and in widths varying from $\frac{3}{16}$ inch to $\frac{3}{4}$ inch on the face. They are formed from rough castings about 18 inches long, which are finally shaped by being passed through a lead vice, which also extends the casting to a length of about 6 feet.

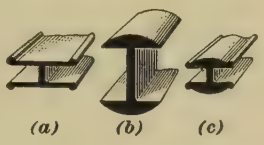

FIG. 18

34. Saddle Bars.—To increase the rigidity of lights formed of leaded glass, iron bars, called **saddle bars,** are introduced at intervals. These bars are built into holes formed for their reception in the wood, stone, or other frame enclosing the light, and are attached to the lead cames by means of copper wire, which is soldered to the lead and twisted round the saddle bar.

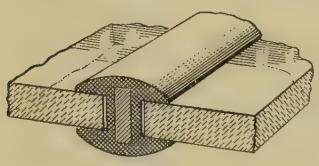
FIG. 19

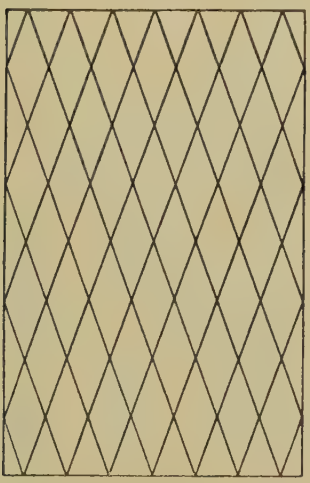
FIG. 20

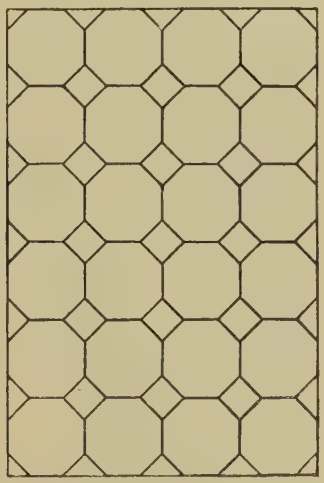
FIG. 21

35. Steel-Cored Lead Cames.—To obviate the necessity for saddle bars, special lead cames, Fig. 19, reinforced with a thin

bar of steel, are now made, and are sometimes preferable. These are not used throughout in the construction of a leaded light,

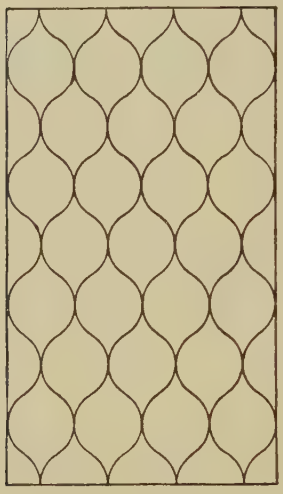

Fig. 22

Fig. 23

but are introduced at intervals sufficiently close to ensure rigidity. Lights so made are neater in appearance than those with saddle bars, but the steel-cored cames require special precautions in soldering, and have rather less attachment into the surrounding frame.

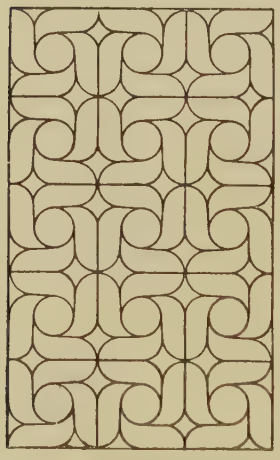

Fig. 24

36. Patterns in Leaded Work. Fig. 20, illustrating the elementary principles of *leading* practised in early times, represents diamonds, or lozenges, and is one of the earliest patterns known. Later, a small geometric pattern, painted in the middle of each piece of glass, was added, the colour being dark reddish, giving a pleasing, diaper effect, while the pattern consisted, in the main, of conventionalized foliage, covering two-thirds of the surface of each lozenge.

Fig. 21 is an octagonal diaper, with lozenges interspersed between the octagons. It is another early form of leaded work composed of straight lines only. Fig. 22 is composed of curvilinear forms, made up of segments of circles and curved lines only. Fig. 23 presents a form of leaded window, composed entirely of curved lines, circles, and semicircles arranged in a foliated pattern. Dating from a much more recent period than the styles represented by Figs. 20 to 22, it shows the progress from the early geometric forms toward the elaborate designs of the present day.

Fig. 24 is a diaper composed of straight and curved lines, circles, and semicircles. This is a geometrical pattern drawn by the aid of squares, a circle being struck from the four corners of each square.

PROPRIETARY SYSTEMS OF GLAZING

37. Patented Systems of Puttyless Glazing.—For glazing large areas such as the roofs of railway stations, markets, etc., putty is unsuitable, being liable to perish and become loose, and requiring frequent attention. Many special forms of glazing dispensing with the use of putty have consequently been devised, and these are rapidly superseding the former methods. An additional advantage for large work is found in certain systems, by which the use of wood is altogether dispensed with, the metal bars to which the glazing is attached being capable of bearing the weight over spans varying in different systems from $4\frac{1}{2}$ feet to $12\frac{1}{2}$ feet.

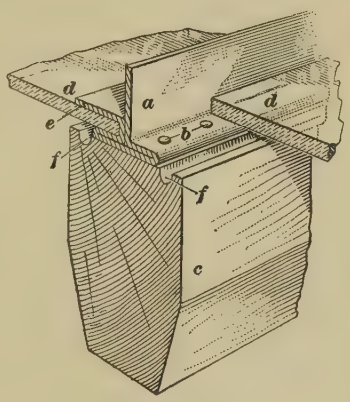

Fig. 25

38. An inexpensive puttyless glazing, known as **Grover's Simplex System,** primarily intended for use in combination with wood rafters, is shown in Fig. 25, and consists of a lead strip which is bent into the form of a ⊥.

This is first affixed with copper nails *b* to the wood rafter *c*, after which the strip is thickly painted and the glass *d* is laid on it, the vertical portions of the strip being then dressed down with a special tool over the glass as shown at *e*. The grooves *f*, *f* shown in the upper surface of the rafter are intended to receive the moisture which is formed by condensation on the inner surface of the glass.

39. A patent bar, known as **Rendle's Invincible Glazing Bar,** formed of sheet zinc or copper, is shown in Fig. 26. This is used for attaching to wood or iron, or may be employed alone in lengths not exceeding 4 feet. The bar is in two portions, the lower part *a* being provided with condensation channels at either side. The upper part *b* is attached to the former, when the glass *c* is in position, by means of large square-headed bolts and nuts *d* at intervals.

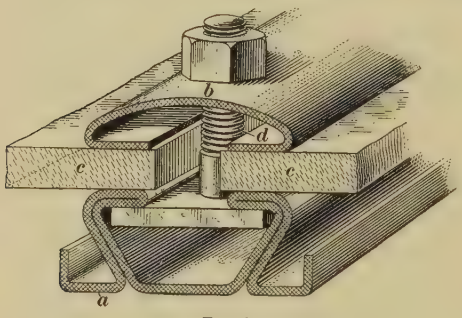

FIG. 26

40. The glazing bar shown in Fig. 27 is known as **Helliwell's Perfection Bar** and is self-carrying. It is made in three sizes, varying slightly, in the form of the rolled-steel bar *a*, these three bars being suitable for spans of 6½ feet, 9 feet, and 12 feet, respectively. The bar *a* is galvanized for protection against corrosion, and the cap *b* is of lead, zinc, or copper, affixed by special clips *c* and bolts and nuts *d*, cords *e e* of asbestos being utilized to form a seating upon the glass shown at *f f*.

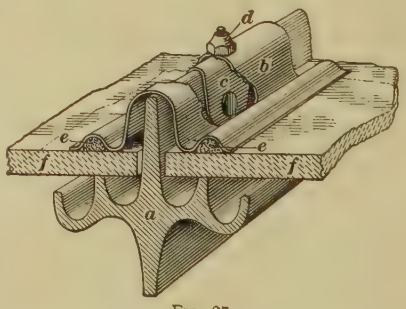

FIG. 27

41. Owing to the difficulty of access to glazing fixed upon high roofs, and to the expense entailed by frequent painting and attention, patent systems of glazing have been devised in which the necessity for painting is obviated, the constructional bars being completely encased in lead. This principle is now greatly in favour and presents many advantages. It should be pointed out, however, that lead-clothed bar systems require intelligent application, as it is essential that the steel bar enclosed in lead should be sealed completely against air and moisture. This precludes cutting and bolting through the bar unless special precautions are taken. Fig. 28 is an example of a self-carrying, lead-clothed steel bar, known as the **British Challenge System Bar.** The bar *a* has lead wings *b* folded over to keep the glass *c* in position, a seating for the glass being afforded by the wedge-shaped cushion of lead *d*, which decreases the liability of fracture.

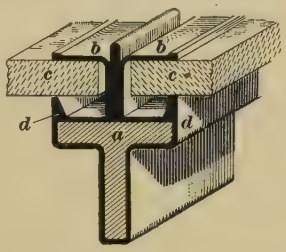

FIG. 28

42. **Electro-Copper Glazing.**—The process of uniting glass with copper by electro-deposition is a proprietary process used in the manufacture of glazing for fire-resisting and other purposes, and is illustrated in Fig. 29. It resembles the leaded glazing previously described, the lead cames being replaced by narrow copper ribbon placed on edge between the panes of glass, to which leaves or flanges of copper are added by electro-deposition. By this means the glass and copper are thoroughly united, and form, with the enclosing frame, a panel of great strength and rigidity, which is air- and water-tight, although the width of the finished copper bar does not exceed $\frac{1}{8}$ inch, and is frequently less.

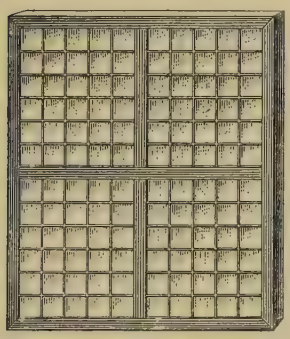
FIG. 29

PAINTING AND DECORATING

(PART 1)

MATERIALS USED IN HOUSE PAINTING

INTRODUCTION

1. Paint being a protective and preservative of both the structural and finishing materials of a building, all work should be painted or varnished according to the character of the material used in construction. The composition of the paint should be varied to suit the particular circumstances of each case. The theory and practice of the painter's art may therefore be considered in regard to both plain surface painting and to decorating, the former dealing with pigments, their processes of manufacture, methods of application, and combination of colours, as well as the material best suited for each particular class or part of the work, regard being had to durability and utility, while the latter discusses the character of the material painted, the combinations of colours applied, and treatment of surfaces that are to receive the colour, exclusively in consideration of the decorative effect.

COLOURS

PRIMARY COLOURS

2. An analysis of white light will show that it is composed of a combination of seven colours: violet, indigo, blue, green, yellow, orange, and red, which vary in quantity. This combination is called the **spectrum,** but the green, orange, violet, and indigo can be produced by the mixture of other colours, so

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that if they are taken from the spectrum only three will remain: red, yellow, and blue. These are termed **primary colours,** since they cannot be divided into any others and exist as a standard from which all other colours can be theoretically made. An illustration of the analysis and decomposition of light may be seen in the rainbow, where the sunlight passing through the drops of rain is refracted and broken into its several colours. A more satisfactory decomposition can be obtained by means of a glass prism, for the colours will appear much clearer.

Of the primary colours, blue possesses that quality which is technically known as *coldness* in colour. In a **chromatic scale,** that is, a colour scale, wherein the various colours are related to one another in the same manner that the various degrees of light and shade are related to one another, from most brilliant sunshine to absolute darkness, blue will be nearest black or darkness. That is to say, blue is the least obtrusive of all the colours, and when used in decoration is the least conspicuous. Blue bears exactly the same relation to absolute darkness, or black, that yellow does to brilliant light, or white. The palest shade of yellow is nearly white, the darkest shade of blue (indigo) is nearly black.

SECONDARY COLOURS

3. Secondary colours are formed by the mixing of any two primary colours; since there are only three primaries there can be only three secondaries. When mixed in pairs, the primaries produce the secondaries, as follows: Red combined with yellow forms orange, but combined with blue, produces violet or purple; yellow combined with blue gives a green.

Orange, green, and violet or purple are, then, the secondary colours. They may, in some cases, be obtained direct from the pigment itself. The combination of one secondary with any other secondary colour will produce a **tertiary colour.**

4. Orange, the first of the secondary colours, in relation to light, is composed of yellow and red. It is said to be true and perfect, when in an equal quantity of surface or intensity it will neutralize a perfect blue. By *neutralize* is meant the

balancing in intensity or prominence. The proportions of a true compound are five of perfect red to three of perfect yellow. When orange inclines to red, it takes the names of scarlet, poppy, etc.; in gold colour, etc., it leans toward yellow. Orange is of the hue and partakes of the vividness of sunshine, as it does also of all the powers of its components, red and yellow. It is pre-eminently a warm colour, being the even contrast or antagonist, in this respect, as it is also in colour, of blue; hence, it is discordant when standing alone with yellow or with red, unqualified by their proper contrasts.

5. Green, the second of the secondary colours, in the general scale of colours and in relation to light and shade, is, in its most perfect hue, composed of three parts of yellow to one of blue of equal intensities. Of all compound colours it is the most effective, distinct, and striking. But greens produced directly of copper, arsenic, etc., are more durable than those composed of blue and yellow.

6. Purple, the third and last of the secondary colours, is composed of red and blue in the proportion of five of the former to eight of the latter. It is, next to green, the most pleasing of the consonant colours. Since blue is its governing tint, it partakes of many of the properties of blue: it is the coolest of the secondary colours, is nearest black in respect to shade, and is never a warm colour. When inclining to red, purple takes the name of crimson; indicative of other shades are the names violet, lilac, etc. Purple may be made by the admixture of ultramarine blue and vermilion, or of Prussian blue and lake, with varied proportions of white, that pigment required to impart a blue tendency predominating. With increased additions of white, the various tints of lavender, lilac, etc., are produced.

SEMI-NEUTRAL COLOURS

7. As colour descends, according to a regular scale, from white and properly terminates with olive, neutral black would here naturally end the series; practically, however, every

coloured pigment of any class whatever combines with black. Hence arises a new series in the scale of coloured compounds, having black for its basis, distinguished by the term **semi-neutral** and divided into three classes: brown, maroon, and grey. Inferior as they are, in point of colour, the semi-neutrals comprehend a great proportion of our permanent pigments, being, so to speak, black tints or shades.

PAINTS

COMPOSITION OF PAINTS

8. All **paint** is composed of two general ingredients: the *pigment* and the *fluid medium*. The former usually consists of a mineral oxide or precipitated vegetable dye, which very largely forms the body of the paint and determines its colour, while the latter consists of the oil, varnish, or water in which the pigment is dissolved or suspended, according to the character of which the paint is termed *oil colour* or *water colour*.

Oil colours are used in all places where the purpose of the paint is to protect as well as to decorate the surface to which it is applied, or where the painted decorations are likely to be exposed to the elements. **Water colours** are used in house painting for decorative effects, and then only in places where they will not be subjected to dampness or strong sunlight. They are also used for graining in the imitations of soft woods.

9. **Pigments** are, according to the base from which they are derived, divided into several classes. The metallic oxides give pigments of various colours, some of which are of great importance to the painter, while others, owing to their chemical influence on other pigments, cannot be mixed to form compound colours.

Various salts of lead produce white, red, and yellow pigments, the most important of which are the whites, as hereafter described. Iron and mercury produce red pigments. The oxides of cobalt give us a valuable shade of blue, and copper forms the base of a number of the most important greens.

The **ochres, umbers, siennas,** etc., are all forms of earth, found in their natural state, already mixed with certain mineral oxides, which impart to them the colours by which they are known.

10. Lakes is the general term given to pigments derived from animal, vegetable, or coal-tar colouring matter. They are usually, according to their particular composition, prefixed by another name to more clearly define them, such as crimson lake, madder lake, etc., madder being the name of that group of pigments made from the colouring matter of the madder root.

11. Carmines are the colouring matter derived from cochineal and form several combinations with madders and lakes, which will be hereafter discussed.

PIGMENTS

WHITE PIGMENTS

12. White lead is a carbonate of lead produced by several methods, the best being obtained by means of the Dutch process, which consists in the taking of gratings of pure lead and exposing them to the fumes of acetic acid. The gratings are, by this treatment, corroded and covered with a crust of carbonate, which is removed and ground to a fine powder.

13. Precipitated white lead is made by suspending rolls of thin sheet lead, or small bars, over malt vinegar or pyroligneous acid in closed vessels, the evaporation of the acid being kept up by heat applied to the vessels, while immersed in a steam bath. The white lead, produced by precipitation, is generally considered inferior to that prepared by corrosion, wanting, as it is, in density or body, and, when mixed with its vehicle, absorbing too much oil. It has, however, one advantage: it requires no grinding to prepare it for use.

14. When not otherwise obtainable, pure white lead may be prepared by the following simple method: An earthen vessel with a cover something like a colander, but having

well-burnt clay bars instead of perforations, is filled with vinegar. For temporary purposes bars of wood will suffice. Narrow strips of common lead rolled into scrolls, from which accumulated oxide or foreign matter have been scraped, are placed on the bars so that they do not touch each other, and the pot is gently heated; the fumes of the vinegar corrode the lead and reduce it to a white powder ready for mixture with oil.

15. The white lead used in oil painting is sold already ground in oil, reduced to a thick paste, much too thick for use, and requiring dilution to bring it to a proper consistency. This is done by placing some of it in a pot, pouring on it a small quantity of oil and turpentine, then stirring the compound thus obtained with a stiff palette-knife or flat stick until the particles of the pigment are all separated and a perfectly smooth mixture obtained. The driers should then be added, and if the mixture should still be too stiff to pass through a tin strainer, or piece of canvas or muslin, it should be further reduced.

16. There are white oxides of lead, the heaviest and whitest of which are the best, being, in point of *colour* and *body*, superior to all other whites. When pure, and properly applied in oil and turpentine, they are safe and durable, and dry well, but excess of oil discolours them, while in water painting they are very changeable, sometimes becoming almost black. They have, besides, a destructive effect on all vegetable lakes, except the madder carmines, and are also injurious to minium, the red and orange oxide of lead; to orpiment, or king's yellow, which is a trisulphide of arsenic; to massicot, the yellow oxide of lead; to patent yellow, a chloride of lead; and to gamboge, a pigment derived from a powdered yellow gum; but with ultramarine blue, vermilion, yellow, and orange chrome, and with the lakes, ochres, and siennas, these whites compound with little or no injury.

17. In oil painting, white lead is essential to form the body and give solidarity in colouring. It is, moreover, when neutralized with black, the best local white. White lead improves with age; old white lead of good quality goes farther

and lasts longer than if used when fresh. It should not be exposed to the air, or it will turn grey. Paint made with fresh lead has, moreover, a tendency to become yellow. Fresh white lead has often a yellowish tinge, caused by the presence of iron.

Lead pigments should not, however, be employed in water colours, distemper, crayon, or fresco painting, for, with all such, they occasion change of colour, either by becoming dark themselves, or by causing the colours with which they might be mixed to fade. Cleanliness in using these colours must be specially enjoined, for, although not virulently poisonous, they are, when taken into or imbibed by the pores of the skin, or otherwise, pernicious, as, indeed, are all pigments of which lead is the basis.

18. Adulteration.—White lead may be obtained either pure, or mixed with various substances, such as sulphate of baryta, sulphate of lead, sulphate of lime, whitening, chalk, zinc white, etc. These substances do not combine so well with oil as does white lead, nor do they so well protect the surfaces to which they are applied.

Sulphate of baryta, the most common adulterant, is a dense, heavy, white substance, very much like white lead in appearance. Absorbing very little oil, it may be easily detected by the gritty feeling it produces when the paint is rubbed between the finger and thumb. In exterior work, where much exposed to the weather, adulterated white lead will turn to a dirty dark colour, giving an appearance somewhat similar to black lead.

The best test for white lead is heat. If a portion is placed in a ladle and held over a gas jet or a fire it will turn to a blue lead if pure; whatever shows otherwise means adulteration.

19. Other White Pigments.—The principal varieties and sources of other white pigments are the following :

Antimony White.—Antimonious oxide.

Body White.—Levigated flake white.

Cadmium White.—Cadmium carbonate or hydrated oxide.

Chinese White.—A zinc oxide.

Constant White.—Barium sulphate.

Derbyshire White.—Ground baryta or heavy spar.

Dutch White.—Three-fourths barium sulphate and one-fourth white lead.

Flake White.—An English white lead, in the form of flakes or scales, from which it derives its name, formed of oxidized carbonate of lead, not essentially differing from Dutch white. Other white leads seldom equal it in body; when levigated, or ground smooth, it is called *body white.* Flake white ranks next in body or density to white lead, and is employed in the better class of work, where great purity of tone is required.

Flemish White.—An artificial lead sulphate.

Hamburg White.—Two-thirds barium sulphate and one-third white lead.

Kremnitz White.—Lead carbonate and hydrated oxide.

Kremser White.—A pure white lead.

Newcastle White.—A white lead made with molasses vinegar.

Pattison's White.—A mixture of lead chloride and oxide.

Pearl White.—Bismuthous oxychloride.

Satin White.—Aluminium and calcium sulphate.

Tin White.—Hydrated tin oxide.

Tungsten White.—Barium tungstate.

Venice White.—A mixture composed of barium sulphate and white lead in equal parts.

Zinc White.—Hydrated zinc carbonate or oxide; it is perfectly durable in oil and water, but unfortunately wanting in body, which renders it less useful to the house painter, who is more restricted as to the thickness and number of coats he applies than is the artist, who, in this respect, enjoys greater latitude. In house painting the use of zinc white is, therefore, resorted to only where extreme delicacy of treatment is demanded, and for curing the evil effects of resinous and otherwise troublesome woodwork.

BLACK PIGMENTS

20. Black, the opposite of white, is the last and lowest in the scale of colours. To be perfect, it must be neutral with respect to individual colours and absolutely transparent, that

is, it must have the quality of absorbing all the rays of light that fall upon it, and reflect none. Its use in painting is to represent *shade* or depth, of which it is the governing element in colours, as white is to *light*. There is, properly speaking, no perfectly black pigment.

Black, more or less, deteriorates all colours with which it is mixed, by neutralizing them and rendering their colour valueless. It is a *cold* colour, that is, it lacks the brilliancy of such colours as red, yellow, orange, etc., and therefore imparts coldness to all colours with which it is mixed; for instance, it gives to red a purplish tinge, it turns yellow into green, and gradually neutralizes white to a bluish grey. It is the most retiring of all colours and communicates this property to other colours in mixture; but when placed alongside of other colours, heightens their effect by contrast; in like manner, it subdues the cold colours by rendering them less conspicuous. Invested with the double office of colour and shade, black is, both as regards use and avoidance, one of the most important colours to the painter.

21. Lampblack is simply the soot obtained by burning resinous woods, tallow, coal tar, etc. It is a purely carbonaceous substance of fine texture and very durable. It may be experimentally prepared by holding a plate over the flame of a candle and collecting the sooty deposit thus obtained. On a larger scale, it may be obtained by suspending a conical metal funnel over a lamp flame, fed with oil, tallow, coal tar, or crude naphtha, through a large bushy wick arranged to generate as much smoke as possible. Large, spongy, mushroom-like accumulations of an exceedingly fine and very black carbonaceous matter gradually form at the apex of the cone, and may be collected from time to time, until a sufficient quantity is obtained. It is in this state very oily, and can be used only as an oil pigment, but if slowly calcined in closed vessels, it is rendered drier and less oily, becoming what is known as **burnt lampblack**, which may be used as a pigment for both oil and water colours.

22. Ivory black and **bone black** differ materially in their intrinsic qualities; each is prepared by charring to blackness,

in a closed vessel, the material that forms its base, and is a perfectly neutral and durable black, mixing well with oil; but the former is superior in quality and may be mixed with certain proportions of white lead to form a beautiful pearl grey. Black, furnished from calcined bones, however, has a peculiar reddish tint which mars it for some purposes; it tends, unless well burnt, toward a brown colour, drying slowly and unevenly. Bone black is cheaper than ivory black, and is, therefore, frequently used where the latter would be more suitable and yield better results.

23. **Frankfurt black** is a pigment prepared from the lees, or sediment of wine, vine twigs, and tendrils, from which the tartar has been washed, by burning in the same manner as ivory black. Similar blacks are also prepared from peach stones, etc., though these are usually distinguished under the names of almond black, peach black, etc.; in India, the shell of the cocoanut is employed for the same purpose.

24. **Blue black** is a well-burnt and levigated charcoal of a cool neutral colour, not differing in other respects from the common Frankfurt black. It was formerly much employed in painting, and, in common with all carbonaceous blacks, has, when duly mixed with white, a preserving influence on that colour. This influence is obtained from two causes: first, chemically through the bleaching power of carbon, and second, chromatically through the neutralizing and contrasting power of black with white. A superior blue black may be made by calcining Prussian blue in a closed crucible, in the manner of ivory black; this pigment has the important property of drying well in oil. Other black pigments may, in this way, be made by charring.

RED PIGMENTS

25. **Red** is the second of the primary colours, standing between yellow and blue; it is also intermediate between white and black or light and shade. It is the second in harmonizing and contrasting with other colours and in compounding black and all neutrals. Red is a colour of double power in that, in

union or connection with yellow, it becomes warm and advancing, but mixed or combined with blue it becomes cool and retiring. Hence, it is pre-eminent among colours, the most positive of all, forming, with yellow, the secondary orange, and its near relatives, scarlet, etc.; and, with blue, the secondary purple, and its allies, crimson, etc. It gives some degree of warmth to all colours, but mostly to those that partake of yellow.

26. Vermilion is an ancient pigment that is both found in a native state and produced from mercury. The Chinese possess a cinnabar so pure as to require grinding only to become very perfect vermilion; they are also supposed to have a process of manufacture, unknown to us, whereby superior brilliancy is imparted to the colour, and the beauty of the natural pigment enhanced.

To test powder vermilion, place a small quantity on a piece of paper laid on a hard surface; cover this with a card or other piece of paper, which rub with the thumb-nail or some hard substance. If the vermilion is pure, it will, on the removal of the card or paper, present a smooth surface of the uniform original colour, but, if adulterated with red lead, etc., it will appear orange or yellow.

27. Red lead is a preparation of lead, made by subjecting massicot to the heat of a furnace, with an expanded surface and free accession of air. It is of scarlet colour and fine hue, warmer than common vermilion. It has been, even in name, confounded with vermilion, with which it was formerly the custom to mix it. When pure, it is unaffected by light; but acids, white lead, or any oxide, or preparation of the metal, soon deprive it of colour, while impure air will blacken and ultimately metallize it. Red lead is used almost exclusively in priming; that is, the first coat of paint applied to new wood work, to counteract any effects of a poisonous nature that might exist in the wood. Red lead is often adulterated with brickdust, but the fact is easily detected by heating the red lead in an iron crucible and treating it with nitric acid diluted: the red lead will be dissolved but the brickdust will remain.

28. Light red is in reality a burnt ochre of russet-orange hue, principally valued for its tints, when mixed with other pigments. The crimson light red is a burnt brown ochre. The principal yellow ochres give this colour best; the brighter and better the ochre from which this pigment is prepared, the brighter will be the red, and the better the flesh tints it will give with white. It is greatly used in figure and landscape painting.

29. Venetian Red or Scarlet Ochre.—True Venetian red is believed to be a native ochre, but the various pigments sold under this name are prepared from sulphate of iron. It is frequently, during manufacture, adulterated with sulphate of lime, but this process increases its bulk and improves its mixing qualities at the expense of depth of colour.

30. Indian red is a ground ore brought from India, but it may, by calcining sulphate of iron, be artificially prepared. Its tints vary greatly, but the best are those of a rosy hue. This pigment, an anomalous red of a purple-russet hue, has good body and is valued, when fine, for the pure lake-like tone of its tint. In its crude state it is a coarse powder full of hard and brilliant particles, of dark appearance, somewhat magnetic, and, on account of a chemical tendency to deepen under this treatment, is greatly improved by grinding and washing. It is, besides, very permanent, unaffected either by light, impure air, or mixture with other pigments. Defying the effects of time or fire, it remains an opaque colour, covering its surface satisfactorily.

31. Lakes are now usually prepared by precipitating coloured tinctures of dyes upon alumina and other earths, etc. The colouring matter of common lake, also known as drop lake, is brazil wood, affording a very fugitive and unreliable colour. Superior red lakes are prepared from lac, cochineal, and kermes, but the best from the root of the madder plant.

32. Scarlet lake is one of numerous lakes made from cochineal, others being Florentine lake, Hamburg lake, Chinese lake, Roman lake, and carminated lake. Cochineal consists of the

bodies of female cochineal insects killed and dried by heat. It is of a deep red colour which, treated with acids, becomes more or less of an orange tint, but if subjected to the influence of an alkali, turns to a violet colour.

33. **Carmine** is produced from *kermes*, the dried bodies of a cochineal-like insect living on certain oaks found near the Mediterranean. Carmines produced from cochineal, by the agency of tin, are of fine powdery texture, velvety richness, and beautiful brightness of colour. This colour is not generally used in house painting.

34. **Rose pink** is a coarse kind of lake, produced by dyeing chalk or whitening with a decoction of brazil wood; it fades quickly, and is chiefly used for paper hangings, etc. Dutch pink is a similar substance, made from quercitron bark.

YELLOW PIGMENTS

35. **Yellow,** bearing the same relation to light as blue does to shadow, is capable of reduction, through several shades, till it merges into a cream white, its colour limit.

36. **Naples yellow** is composed of the salts of lead and antimony, owing its name to the fact that it is supposed to have been first obtained from a volcanic product of Mount Vesuvius, near Naples. It is a very opaque pigment, and therefore covers thoroughly the surface to which it is applied, but is not so brilliant as chrome yellow and is very difficult to grind.

37. **Chrome yellow,** one of the most durable of pigments, is obtained from the subchromate of lead. Frequently adulterated with gypsum, it is prepared by mixing diluted solutions of acetate or nitrate of lead and bichromate of potash.

38. **King's yellow** is the name of a very dangerous and unsatisfactory pigment obtained from arsenic. It is not very poisonous, but injurious to other colours when mixed with them. Least durable of all the yellow pigments, it is known, also, under the names of yellow orpiment and Chinese yellow.

39. Yellow ochre is a natural clay, coloured by oxide of iron, found abundantly in many parts of England. **Stone ochre** is a similar pigment, found in the form of balls embedded in the stone of the Cotswold Hills, England. It varies in tint from yellow to brown.

40. Yellow lake is the name given to several pigments which vary in colour and appearance, according to the colouring substances and the modes of preparation used. Usually in the form of drops, their colours are ordinarily bright yellow, very transparent, and not liable to change in an impure atmosphere—qualities of undoubted value.

BLUE PIGMENTS

41. Prussian blue is made by mixing yellow prussiate of potash with some salt of iron. This prussiate is obtained by calcining and digesting old leather, blood, hoofs, and other animal matter, with carbonate of potash and iron filings. The pigment dries well with oil and is much used for mixing dark blues, for making purples, and for intensifying blacks. Slight differences in the manufacture give considerable variation in tint and colour, which causes the material to be known under various names, such as Antwerp blue, Berlin blue, Chinese blue, etc.

42. Indigo blue is a pigment manufactured in various qualities and has been used for many centuries in dyeing processes. In painting, it is not so bright as Prussian blue, but is extremely powerful and transparent, and may be substituted for some of the uses of Prussian blue, as the latter is for indigo.

Indigo blue is of great body, and glazes and works well, both in oil and water; but its relative permanence as a dye has obtained for it a false character of extreme durability in painting, a quality in which it is very inferior, even to Prussian blue. By the statement that indigo blue *glazes* well is meant that it forms a good body or under colour on which can be spread a lake or other transparent colour to add depth and richness to the under colour. This transparent outer tint is termed **glazing colour.**

43. Indigo blue is generally prepared by the fermentation of a glucoside existing in a number of plants of which those obtained from India are the most important. The leaves of the plant are pressed into stone tanks and allowed to soak for about 12 hours in water. Fermentation, in which bacteria play a part, soon commences, with the formation of a yellow liquid, which is run off and agitated with air. The liquid turns green and then blue, and after being allowed to settle is drawn off from the sediment. It is then boiled, washed, and strained off and pressed and cut up into cubes, which after drying are sent into the market.

Natural indigo is being supplanted by a synthetical product formed by heating isatin with phosphorous trichloride and acteyl chloride. Many simpler processes have been elaborated by which artificial indigo is manufactured on a profitable scale with naphthalene, one of the chief component parts of coal tar, as the starting point. Probably neither the artificial nor the synthetical indigoes are pure compounds.

44. **Ultramarine blue** is a pigment obtained from the precious blue stone known as *lapis lazuli*, but its costliness places it outside the colours commonly used in house painting. Its beautiful shade, however, causes its name to be applied to several imitations or artificial ultramarines, of which the French and German are the most satisfactory. Artificial ultramarine is prepared by fusing in closed crucibles a mixture of soda, silica, alum, and sulphur, and reheating the greenish product thus obtained until the blue pigment appears, when it may be removed and ground up for use. There are several compositions of this blue, all differing in shade, and, being very cheap products, are largely used by the decorator.

45. **Brunswick** or **celestial blue** is made by precipitating the alumina from a solution of alum with carbonate of soda, washing the precipitate, and adding sulphate of baryta, sulphate of iron, yellow prussiate of potash, and some bichromate of potash. When dried, this mixture is known as Brunswick or celestial blue, but when the sulphate of baryta is left out, and the material is not dried, it is called *damp blue.*

46. Cobalt blue is the name now appropriated to the modern improved blue pigment prepared with metallic cobalt, or its oxides, although it properly belongs to a class of pigments, including Saxon blue, Dutch ultramarine, and Hungary blue. These differ principally in their degrees of purity and the nature of the earths with which they are compounded. The first is the finest cobalt blue, and may not improperly be called a blue lake, the colour of which, like enamel blues, is brought out by fire. When well prepared, it is of a pure blue colour, superior to all other blue pigments. It resists the action of strong light and acids, but its beauty declines by the action of time and impure air.

GREEN PIGMENTS

47. Chrome greens are compound pigments of which chrome yellow is the principal colouring substance. They are also called Brunswick green, etc., which are compounds of chromate of lead with Prussian and other blue colours. There is one true chrome, or native green, the colouring matter of which, being the pure oxide of chromium, free from lead, is enduring against the action of sunlight and of impure air. True chrome greens neither inflict upon, nor receive injury from, other pigments, and are eligible for either water or oil painting, in the latter case drying well as a rule. They likewise afford valuable colours in enamel painting.

48. Brunswick green is one of a large class of pigments, grouped under the name of copper greens, some of which call for special mention.

49. Verdigris is an acetate of copper of bright colour, inclining to blue, and is the least permanent of the copper greens, soon fading and becoming white by the action of light, particularly in water colours.

50. Emerald green, for purposes of commerce, is made of verdigris mixed with a solution of arsenious acid ; it is brilliant in colour, very poisonous, difficult to grind, and very transparent, requiring at least three coats to make it solid.

51. Scheele's green is a compound oxide of copper and arsenic, and is very poisonous.

52. **Made Greens.**—Several other greens are made from copper, such as Brighton green, malachite, mountain green, marine green, Saxon, African, French, patent green, etc. Mineral green is the commercial name of green lakes prepared from sulphate of copper. It is a good durable colour for house painting, made from bibasic carbonate of copper. The shades of green in use to-day are multitudinous and are termed **made greens,** a few of which are: *Electric green,* made with chrome and Prussian blue; *antique* and *duck's-egg green,* with chrome and black; *sea green,* with chrome and green. These can be altered to any shade or hue to suit the required taste.

BROWN PIGMENTS

53. **Umber** is the name of a brown pigment obtained through the agency of oxide of iron from naturally coloured clays, some coming from Turkey and some from Umbria, in Italy, whence the colour takes its name. In its natural state it is usually designated as **raw umber,** while **burnt umber,** a darker pigment, is obtained by calcining raw umber at a low temperature.

54. **Vandyke brown** is a species of bog earth of a fine, deep, semi-transparent brown colour much used when ground in water for graining purposes.

55. **Raw sienna** appears to be an iron ore, considered as a crude natural yellow lake. Valuable, very absorbent, and firm in substance, it presents, when broken, a glossy surface. It becomes, by burning, a deep orange, more transparent and quicker in drying, and is a valuable colour in graining.

56. **Sepia** is a brown pigment originally obtained from the excrescence of the cuttlefish. Of a powerful dusky brown colour and fine texture, it works admirably in water, combines well with other pigments, and proves very permanent in results. It is mainly used as a water colour on account of its reluctance to dry in oils.

CLASSIFICATION OF PIGMENTS

57. The various pigments may, according to uses and characteristics, be classified:

1. Those which are more or less transparent and fit for graining and finishing are: all blacks (except mineral blacks), umbers, chrome greens, cadmium yellow, raw and burnt sienna, ochre, French ultramarine, and brown sepia.

2. Those which are little, if at all, affected by heat or fire: the whites and the ochres, in natural clays.

3. Those which are for fresco or distemper work: the whites made from sulphate of baryta or carbonate or sulphate of lime, all the ochres, the reds, blues, browns, and blacks.

4. Those which are more or less injured by damp and impure air, especially sulphuretted hydrogen, and are unfit to use in distemper: white lead, all the yellows, except the ochres, red lead, Chinese and Persian lead, Prussian and cobalt blues, orange salts of lead, and all greens.

5. Those which fade or are affected by strong light: all vegetable colours, including the yellows, Prussian blue, indigo, the peaty browns to a considerable extent, and, in less degree, the madders.

VEHICLES

OILS

58. **Oil** is one of the fluid mediums in which a pigment is so suspended that the painter may spread it properly and cause it to adhere when dry. It is termed the *vehicle*, because it serves to carry the pigment evenly over the surface to which it is applied, and is usually combined with some other medium, or subjected to some special preparation, to give it the drying qualities it seldom in itself possesses. The medium so added is called a *drier*, and is varied in material and quantity according to the character of the oil with which it is mixed.

59. **Linseed Oil.**—The oil most generally used by the house painter is obtained by the compression of flaxseed. It varies

greatly in quality, as well with reference to the seed from which it is extracted as in respect of age and consequent clearness. When a large quantity is kept stored for six months or more, refuse forms at the bottom which cannot be used, save in mixing coarse paint for outside work, but the clear oil can be drawn off from above the refuse and used. Linseed oil is, from its cheapness, the oil most used for house painting, but should only be used where white lead plays a leading part in the paint, and should not be used when dry colours form the body, boiled linseed oil being the proper vehicle for all powdered or dry colours. The marked defects in linseed oil are its brown colour and its tardiness in drying. These defects may, however, be greatly diminished, if not entirely removed, by keeping the oil for some time before using ; it then becomes a good vehicle for colour without any mixture. Nevertheless, it is generally used with a proper drier, and it never by itself becomes sufficiently pure to use with white or other light tints without imparting a brown colour. The drying of raw linseed oil may be accelerated by adding about 1 pound of white lead to every gallon of oil, and allowing it to settle for at least a week. Not only is the colour of the oil thus improved, but the lead may be afterwards used for ordinary work.

60. Several methods have been devised for bleaching and purifying linseed oil, but there is no known process for entirely preventing discoloration after drying. One method is to drop into a bottle or jar of the oil some powdered whitening. The mixture is then stirred, or shaken, and then placed in a warm oven. The whitening will very soon carry down all colour and impurity, and form a precipitate at the bottom ; the refined oil at the top may then be drawn off. In the rare instances, wherein the least yellowness in the oil might prove injurious, nut or poppy oil may, with advantage, be used, but linseed oil, for general purposes, is to be preferred.

Linseed oil is sometimes boiled with litharge to cause it to dry quickly, but when thus treated is unfit for the better classes of work. The quality of linseed oil may be determined by looking toward the light through a vial filled with it. If poor in

quality, the oil tends toward opacity, appears turbid or milky, while its taste is strong and rancid. Good fresh oil should be, in appearance, clear and pale; in taste, sweet, and emit little or no odour.

61. Boiled linseed oil, usually designated **boiled oil,** is prepared by heating raw oil with certain driers; the drying qualities of the oil are greatly improved by the boiling. To be used with zinc paint, boiled oil must be free from oxides of lead.

62. Nut oil, an almost colourless transparent oil, is expressed from the walnut. It dries more rapidly than linseed oil, and is, owing to its lack of colour, used for white and other light paints.

63. Poppy oil is colourless, and, in some instances, used for delicate work, where the time required for drying is not limited. For strength and durability it stands second to linseed oil.

TURPENTINE

64. Turpentine is the resinous exudation of various coniferæ. That from Pinus australis (American), Pinus pinaster (French), Pinus sylvestris (Russian), and Pinus larix (Venice) is the most popular. On distillation by fire, heat, or steam, *oil* or *spirit of turpentine* passes off, leaving colophony or resin. The volatile portion consists mainly of terphenes. Oil of turpentine is a colourless liquid of characteristic odour. It boils at about 320° F., and is a good solvent for oils and resins, being used for this purpose in the preparations of paints and varnishes. Russian turpentine, which does not dry properly and gives off a powerful odour, should not be used.

DRIERS

65. Definition.—Driers are substances added to paint to cause the oil to thicken and solidify more rapidly. It is thought that they carry to the oil the oxygen needed to enable it to dry. A very small quantity yields quite extensive results. These

driers are ground up in oil and mixed in small quantities with the suspended pigment. Some colours will not dry without driers, but remain tacky and thereby exposed to much injury, through the accumulation of dust and the degeneration of the tints.

Driers should not be used with pigments that dry well in oil colour. If used in excess they not only retard the drying but injure, and may destroy, the paint. They should not be added to the colour until it is ready for use, neither should more than one kind of drier be used to the same lot of paint.

66. Varieties of Driers.—The following is a list of driers, each of which is suited to some particular quality or colour of paint :

Red lead is a good cheap drier, but can, of course, be used only in situations or in paints where its colour is unobjectionable.

Sugar of lead, ground in oil, is the best but most expensive of all driers, and is used as a drier especially for light tints.

Litharge, the drier most commonly used, is produced in the oxidization of lead containing silver.

Massicot is a superior kind of litharge, produced by heating lead to a degree insufficient to fuse the oxide.

Oxide of manganese, being of a very dark shade, is seldom used except for the deep colours.

Sulphate of manganese is the best drier for zinc white.

French powdered driers, recommended by the French Medical Faculty to obviate the evil effects of white lead, are a good medium, giving the paint a hard surface without discoloration.

Japanner's gold size is, for some purposes, an excellent drier.

67. Patent driers containing oxidizing agents, such as acetate of lead, litharge, etc., are ground and mixed in oil, ready for immediate use. Some of the inferior descriptions, depending for their drying qualities on lime, should be avoided.

Terebene is a powerful drier, used as a substitute for patent driers, and mixed in the proportion of 1 ounce of terebene to 1 pound of paint, will dry in about half an hour, which is always a danger to the durability of the work.

VARNISHES

DEFINITION AND QUALITY

68. **Varnish** is a solution of certain gums or resins in alcohol, turpentine, linseed oil, or the like, and is applied to produce a hard, shining, transparent coat on the surface. The oil dries, but the alcohol and turpentine evaporate, leaving, in either case, the fine transparent film of resin over the surface varnished. The quality of a varnish can be determined by the time it takes to dry, good varnish taking from 12 to 24 hours to harden, and cheap varnish a much shorter time. The resulting film should be hard and tough and yet not so hard that it will crack. The gloss should be permanent and clear, and should remain durable even when it has been executed for some time.

The value of a varnish depends almost entirely on that of its constituents, but much care and skill are demanded in mixing and boiling the ingredients. Varnish is used to give brilliancy to painted surfaces and to protect them from the action of the atmosphere. It is often applied to plain unpainted wood surfaces to intensify and brighten the ornamental appearance of the grain. It is also applied to papered walls, after the surface has been well sized. A flat varnish is sometimes used to give a dead appearance, similar to that of a flatted coat of paint.

The resins from which varnishes are most usually made are, in general appearance and characteristics, very much the same, but differ in name, according to the tree or shrub from which they are gathered, and, in most cases, give their names to the varnish into which they enter. Thus, we have copal varnish, dammar varnish, mastic varnish, shellac varnish, etc., each of which is made from the gum its name indicates.

69. **Copal varnish** is used for the best work and takes about 24 hours to dry, depending on atmospheric conditions. Inferior

hard resins are sometimes used in place of copal gums, mixed with a solution of turpentine and linseed oil, both of which enter into the composition of the ordinary copal varnishes. As copal swells while dissolving, its solutions and varnishes contract and consequently split in drying, making unsightly fissures, against which linseed oil is the essential preventive. The mixture of copal varnish and linseed oil is best effected through the medium of oil of turpentine, heat being for this purpose sometimes requisite. White copal varnish is similar, but of a lighter colour. Copal varnish should not be used until it is three or more months old.

70. White hard spirit varnish is a composition used very largely for japanned work.

71. A varnish suitable for ordinary work can be made by mixing 3 pounds of powdered resin with $2\frac{1}{2}$ pints of oil of turpentine, then letting it stand for a day or two, shaking it occasionally. Five quarts of boiled oil is then added, the whole well shaken, and then placed in a warm room until clear. The clear portion is then poured off for use, and may be reduced in consistency by the addition of turpentine. This varnish is intended for protecting surfaces against the effects of exposure to the atmosphere, and has been used with advantage where no direct impairment by wear is involved. Unable to resist the effect of constant wear and less brilliant than other varnishes, it is unfit for fine results or for work subject to continual usage.

72. White lac varnish is prepared by dissolving in alcohol or spirits of wine the lac resin of India, chemically deprived of all colouring matter and purified from extraneous substances with which it is naturally combined. The varnish it affords, without this purifying process, is opaque, dark in colour like the japans and lacquers of the East, but when thus purified is brilliantly transparent, very hard, and nearly colourless. This, being a spirit varnish, requires a warm temperature, helpful, indeed, to all varnishes, and enjoys the valued distinction of drying rapidly.

White lac varnish being somewhat costly, its place is often filled, in ordinary work, by the common **white shellac varnish,** consisting of the softer resins dissolved in alcohol with shellac.

73. Spirit varnishes or lacquers are made with softer gums, dissolved in spirits of wine. They dry more rapidly and become harder and more brilliant than turpentine varnishes, but, possessing no powers of durability, are very rarely used and then only for furniture or on papers of a delicate tint. They must never be applied to ordinary work either indoors or out, for scaling and cracking would result.

74. Turpentine varnish is not very durable, will not stand washing, and should be used only for varnishing wall papers or for adding to other varnishes to give them body.

75. Water varnish consists of shellac dissolved in hot water, with just so much of ammonia, borax, potash, or soda as will dissolve it. The solution makes a varnish that will just bear washing.

76. Flat or flatting varnish, for giving a dull effect to the work, is easily procured by taking 3 parts turpentine and 1 part copal varnish with a small quantity of gold size to fix it.

77. Defects.—Some of the defects of varnishing are: *Shrivelling and running*, caused by too much being laid on. *Cissing*, or *running off*, to remedy which the work should be well leathered before applying varnish. *Blooming*, caused by a defect in the manufacture of the varnish, the only remedy for which is to revarnish with a different varnish. *Splitting and cracking*, caused by the use of common varnish.

ENAMEL PAINTS

78. Enamel Paints.—A number of patent enamel paints can be obtained in liquid state and ready for applying; they give hard, enamel-like surfaces that are practically proof against the penetration of damp, so that they can be kept clean by washing. Good enamel paint produces a very highly finished surface, but

great care must be exercised in putting it on, for if put on too thick it will run and, settling in places, will crack when dry. The wood or other material to which enamel paint is to be applied should be primed and painted four coats of good oil colour before commencing with the enamel paint, and each coat when dry should be carefully rubbed down with sand-paper before the next coat is applied.

STAINS

COMPOSITION AND CLASSIFICATION OF VARIOUS WOOD STAINS

79. Stains are liquid preparations of different tints, applied to the carefully prepared surface of the cheaper woods, such as fir, pine, etc., in order to give them the appearance of the more rare and expensive woods, such as rosewood, mahogany, walnut, etc. The process of staining consists, in the main, of laying on the stains in the form of mere washes, so as to change the shade of one wood to that of another which, in its natural grain, it resembles. The stain is applied with a sponge or large brush, the wood having been previously well oiled and glass-papered to help it to take the stain evenly, and the dust resulting carefully removed. The stain should be sparingly applied and well rubbed in, the desired depth of colour being obtained by several washes rather than by one dark and heavy one. The stain should be tested before application. Spongy wood can be filled up with varnish and sand-papered down.

The preliminary operation of sizing requires some care. To be rapidly and evenly spread, the size must be applied with a large brush, and should be quite hot and very thin. In the case of hard woods, the tinting colours should be added to the filler before staining.

80. Stains suitable for different kinds of woods may be prepared as follows:

Mahogany Stain.—A thin mixture of burnt sienna, ground in vinegar, may be used, and grained and shaded while wet with the same, thickened with more sienna.

Black Walnut.—The same as the preceding, but using burnt umber for burnt sienna.

Walnut Stain.—Boil together, for 10 minutes, 1 quart of water, $1\frac{1}{2}$ ounces washing soda, $2\frac{1}{2}$ ounces Vandyke brown, and $\frac{1}{4}$ ounce bichromate of potash.

Oak Stain.—Dissolve 2 ounces of American potash and 2 ounces of pearlash in 1 quart of water; keep corked, and for lighter tints dilute with water.

Black Stain.—Boil $\frac{1}{2}$ pound logwood in 2 quarts of water; add $1\frac{1}{2}$ ounces verdigris, and $\frac{1}{2}$ ounce copperas; strain; put in $\frac{1}{2}$ pound rusty filings; apply two coats.

Red Stain.—Use a solution of dragon's blood in spirits of wine.

Green Stain.—Dissolve verdigris in hot vinegar and add a little indigo. A good green can be got by giving the work two coats of green and one of black as a glaze.

81. Fuming.—By fuming is meant the impregnating of the fibres of a wood with ammonia, which gives a very pleasing effect to oak or mahogany. If small pieces of the wood are to be treated, they can be placed in a large box (for large pieces an air-tight room is used) containing an earthenware pan filled with liquid ammonia. In time, the wood absorbs the ammonia fumes and acquires a richness of colour to be obtained in no other way. A quick method of obtaining an effect similar to this is to brush the wood with liquid ammonia greatly diluted with rain-water, but this method is not to be recommended.

82. Creosote Stain.—Creosote, in the form of stain, is rapidly becoming a substitute for paint for certain purposes. Entering closely into the structure of the wood, it permits the evaporation of any moisture, while paint, having no preservative qualities in itself, merely forms a coating impervious to air and water, so that if the wood has not been completely seasoned before painting, the imprisoned moisture will, in time, produce decay. It is transparent and, instead of hiding, renders the grain of the wood more prominent; besides, it never turns black—a conspicuous fault of other stains and many paints. Creosote stains are now used instead of paint on parts of buildings much subjected to wet, especially shingles, fences, etc.

The cheapness of this stain, both in material and cost of application, is a factor of considerable importance. The very best qualities do not cost probably one-half as much as paint, and any person can do the work quite rapidly and with good effect, so that the labour of applying it is also much less.

83. Creosote bleaching oil is used for producing a silver-grey effect on wooden roofing shingles. This material, at the time of its application, colours the wood to a slight degree only ; a few months' exposure to the weather, however, bleaches the surface of the shingles to a beautiful silken silver-grey. This charming colour improves with age, and never calls for renewal, while the creosote preserves the wood, and prevents mildew and the consequent blackening of the shingles. The creosote bleaching oil should be used on new work only. Its covering capacity is about one-fifth less than that of the ordinary stains.

METHODS EMPLOYED IN HOUSE PAINTING

TOOLS USED BY PAINTERS

GRINDING TOOLS

84. Muller and Slab.—As the pigments used in painting are received from the manufacturer in the form of powder, they must be mixed or ground in oil before they are ready for use. When ground in large quantities by manufacturers, this work is done in a colour mill and the pigments are sold in the form of a thick paste ; but painters may mix their own colours by grinding the pigments on a slab with a muller, which is shown in Fig. 1.

Fig. 1

The muller is a semi-ellipsoidal stone, about 4 inches broad across the flat base, and sufficiently high for it to be grasped by both hands. Mullers

smaller than this are likely to become rounded on the flat surface from unequal pressure, and in this condition are practically useless. A flint stone flat on one end makes a capital muller.

The **colour slab** is a flat piece of close-grained stone, upon which the pigment is placed preparatory to grinding. Colours ground by mill cost less and are more satisfactory than those ground by hand.

85. Grinding is accomplished by mixing the powdered pigment with a sufficient quantity of oil to form a thick paste, and grinding it under the muller by moving the latter backwards and forwards under pressure, lifting the advancing edge sufficiently at each stroke to cover the pigment that has been squeezed out from underneath. The pasty colour must be frequently scraped up from the edges of the slab and deposited in the centre to come under the strokes of the muller ; this is usually done with a thin blade called the *palette knife*. After sufficient colour has been ground on the slab, it is scraped up with the knife, placed in a paint pot, and thinned down with oil to the proper consistency. The operation of grinding with the muller may have to be repeated several times in order to prepare a sufficient quantity of paint, but not till it is all ready is it thinned down for use ; a quantity of drier may then be added, to cause the paint to harden more quickly, or varnish put in the mixed colour to cause it to dry with a glossy surface.

In preparing paint for use, boiled oil is generally used to thin it down when it is intended for outside application, unless it is for decorative work, in which case a little turpentine and some pale linseed oil may be added. For indoor work, linseed oil, turpentine, and a little drier are generally used in varying quantities, according to the finish desired. The smaller the proportion of oil used, the less will be the gloss and the greater the ultimate hardness of the coating.

86. Palette Knife.—As shown in Fig. 2, the **palette knife** consists of a flexible steel blade, with dull edges and a rounded end, set into a hardwood handle. There are several sizes,

varying from 4 to 12 inches in length, but the larger ones are usually termed **stone knives**, as they are never used for any other purpose than mixing the pigment and oil for the slab, while the palette knife is also used for mixing colours on the palette.

FIG. 2

87. **Stopping Knife.**—Another blade used by the house painter is the **stopping knife**, shown in Fig. 3. This is a stiff blade used to stop or fill cracks, nail holes, etc., with putty before the painting is proceeded with. Stopping is not resorted to until after the first coat of paint, called *priming colour*, is laid on, as the pores of the wood are likely to absorb the oil from the putty, and render it brittle and inadhesive.

FIG. 3

88. **The Palette.** The decorator prepares his colours on the **palette**, Fig. 4. The various colours are mixed upon it with the palette knife until the desired shade is obtained, then from this the colour in the paint pot is tinted.

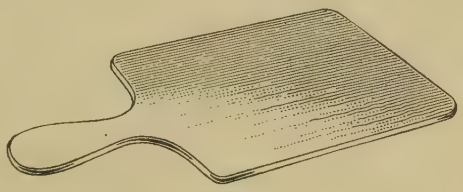

FIG. 4

BRUSHES

89. **Brushes** are of various shapes and sizes according to the different purposes for which each is used, and are made of different materials, adapted to suit the character of the work and vehicle to be spread. Hog's bristle, camel's hair, badger's hair, and sable are the most common materials used in the manufacture of paint brushes, though bear's hair and ox hair are also utilized for special work.

90. **Pound Brushes**—The largest brushes, such as shown in Fig. 5, are made of bristle and are called **pound brushes**.

They vary in size, being distinguished under the marks, "1 oz.," "2 oz.," "3 oz.," etc., up to "8 oz.," which is the largest size, and are made in three shapes, round, flat, and oval, with flat

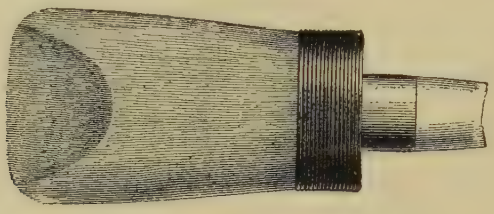

Fig. 5

or chisel-shaped edges. The round and oval brushes are used most frequently, as they hold a considerable quantity of paint, and will spread it over a large surface without redipping. There is a similar brush, made solely for dusting, 4 to 6 inches wide, $1\frac{1}{2}$ inches thick, with common black hair.

91. Tools.—The bristle brushes, next smaller in size to the pound brushes, are classed under the general name of **tools,**

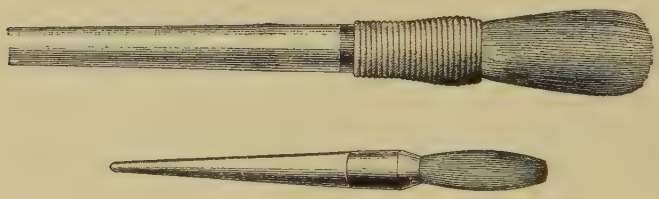

Fig. 6

but are, in some cases, distinguished under a qualifying term, such as *sash tools*, etc., two of which are shown in Fig. 6.

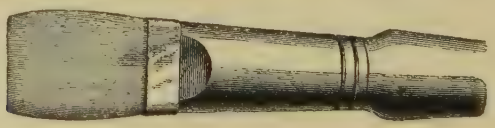

Fig. 7

. **Fitches** are flat, as shown in Fig. 7, or round, and are used in connection with pound brushes to spread the colour on the

more inaccessible parts, such as the mouldings round panels, sash bars, dentil courses, railings, and all other parts where the larger brush would be too cumbersome. Fitches, like tools, are usually qualified by another name to designate their particular purpose. Figs. 8 and 9 show two sizes, known as the **lining fitch,** used in connection with a straightedge to

FIG. 8

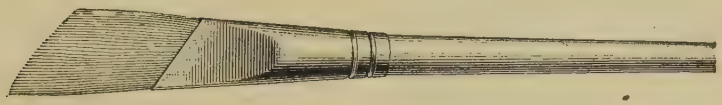

FIG. 9

produce straight lines or stripes. In the smaller size, the bristles are held in place by a piece of tightly wound cord, while the larger one is bound in tin.

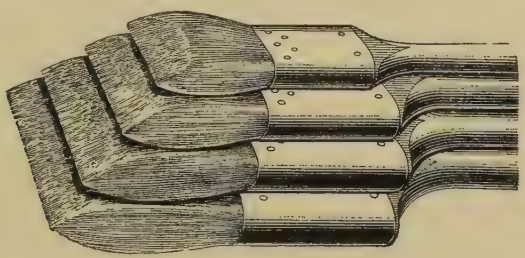

FIG. 10

92. Varnish and **enamel brushes** are usually flat with a chisel edge, and made of a finer quality of hair than the ordinary

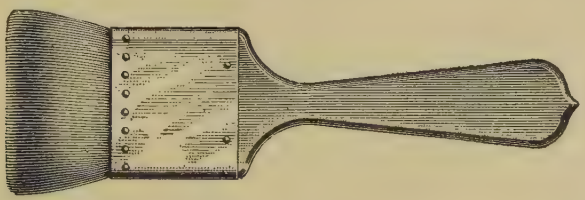

FIG. 11

paint brushes. Black-bristle oval-shaped varnish brushes are used for ordinary work, but for the better class of work the

flat ones, which may be obtained in sets of four, as shown in Fig. 10, are used. For furniture and other fine work, camel's-hair, badger, or sable varnish brushes, such as are shown in Fig. 11, should be used. All varnish brushes should be thoroughly washed after each using, hung up by the handles, and laid over a ledge to dry or else kept in linseed oil, so that the bristles will not become bent or in any way put out of shape. The larger paint brushes may be readily preserved in a soft condition by boring holes through their handles and suspending them in a tub of water on nails driven for the purpose, as shown in Fig. 12. The water should just cover the bristles and not reach the binding, as the latter is likely to swell and burst if permitted to get thoroughly soaked.

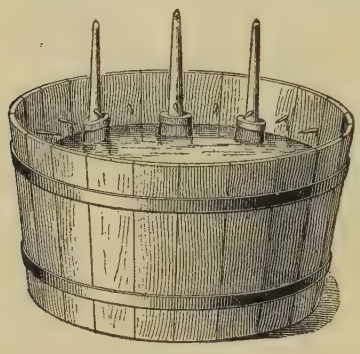

FIG. 12

PAINTING

APPLICATION TO WOODWORK

93. New Work.—Before painting, all glue spots, etc., must be cleaned off with the stopping knife, care being taken not to score or dent the surface of the wood. The dusting brush should, in this part of the work, be freely used.

94. Knotting.—Wood should be thoroughly dry before being used; but as this is not within the painter's control, he must do his best to counteract all neglect in this respect. To prevent their appearance in the finished work, all knots must be covered with some substance that will arrest their absorbent quality or close the apertures of the fibre and thus prevent the effusion of gum or sap; this operation is called **knotting.** Sometimes the resin can be drawn from the knots by heat from a blow lamp.

The object of painting being to preserve the more perishable parts of the structure from the deleterious effect of weather, heat, gases, etc., it is well to note that paint, applied to unseasoned wood, confines the sap and moisture, and thus hastens decay. **Patent knotting** is a specially prepared composition readily purchasable. The following recipes are, however, given for the preparation of like compositions :

1. Mix together $\frac{1}{4}$ pint of japanner's gold size, 1 teaspoonful of red lead, 1 pint of vegetable naphtha, and 7 ounces of orange shellac. Keep in a warm place till the shellac dissolves ; this mixture must be frequently shaken.

2. Mix together, with glue size, a small quantity of white and red lead powder, and apply while warm.

3. Mix together $\frac{1}{2}$ pound orange shellac, $\frac{1}{2}$ ounce pale resin, and 2 pints methylated spirits ; while dissolving, keep covered to stop evaporation. Lightly cork, run through sieve after 14 days, and use the top portion.

The knots should, in certain extreme cases, be covered with silver leaf.

95. Stopping is the filling in and making good of all nail holes, bad joints, splits, etc., with putty, or with a paste made of putty and white lead, called *hard stopping*, which is done with the stopping knife. This is an operation that demands care and attention. It is not sufficient to merely press a small quantity of stopping into the interstices and then smooth it over, for, as the stopping dries, it contracts and sinks below the surface, leaving openings quite as great an eyesore as ever. With the stopping knife slightly raised above the surface, the stopping should be forced as far into the crack as possible. In a day or two before the second coat is added, the stopping will, owing to shrinkage, be found nearly level with the panel, and may then be smoothed with the stopping knife.

96. Where a panel or other part of the work receives a blow, and a dent or shallow concavity is formed, the mere film of stopping required to level such a spot is almost certain to peel off, leaving a place totally uncovered by paint ; to avoid this result, deepen the recess in parts, by pricking holes in it with a bradawl,

which should incline in different directions. Deep fissures are thus formed into which the stopping is forced, and the portions spread over the dents will be, as it were, nailed to the wood by the filaments penetrating these openings. The surface having been again smoothed off with glass-paper, the second painting is proceeded with.

A good filling for rough new or badly bruised work is dry white lead mixed into a paste with gold size and a little turpentine. Spread all over the work with a wall scraper or broad knife, and when dry smooth with glass-paper.

97. Priming.—In all well-built structures, the woodwork receives at least four coats of paint. The first coat, called **priming**, is applied for the special purpose of diminishing the absorbent quality of wood or plaster. This is generally a mixture of white lead and red lead, with a proper proportion of driers; but when the finishing colours are to be of sombre hue, the priming coat may be dark green, dark brown, etc. The painting may be done with a dull lead colour, made of vegetable black and white lead in equal quantities. These colours should be mixed with boiled oil for outdoor, and linseed oil for indoor, work, adding in either case a small quantity of turpentine, the proportion being three parts of oil to one of turpentine. For rapid absorption by the new wood or plaster, the priming coat should be thin. Some painters adopt the reprehensible practice of laying a coat of size over the wood; no durable effect is thereby obtained. The size, to a great extent, arrests the absorbent powers of the wood or plaster, but prevents the proper adhesion of oil paint, which splits and peels off. Size is used sometimes on old work, but it is much wiser to thoroughly clean away the grease with soda water, well rubbing down with pumice stone and washing with clear water. For quickness a little patent knotting or white lacquer placed over the greasy parts will help.

When thoroughly dry, the priming should be rubbed down with glass-paper. This operation, although in itself simple, requires care to make the rubbing equally effective over the entire surface, so the glass-paper should be wrapped round a flat piece of wood or cork (cork being preferred), say 6 in. × 4 in. and 1 inch thick.

For use on the edges of panels and similar situations, glass-paper may be wrapped over a piece of chisel-shaped wood, while for the curves of mouldings a piece of cloth round the end of the finger is used.

98. Intermediate Coats.—For the second coat, white lead thinned with oil and a little turpentine and driers may be employed, the proportion of driers for ordinary cases being $1\frac{1}{2}$ ounces to 10 pounds of white lead; but in winter, or in a damp climate, the proportion of driers must be increased. It should be observed that second colour for new work is made up chiefly with oil, as it best stops the suction of the wood; but second colour for old work is made up chiefly with turpentine, because oil would not, in this circumstance, either dry or adhere so well.

The colour should be spread on as evenly as possible. To effect this, as soon as the whole or a convenient quantity is covered, the brush should be passed over it in a direction at right angles to that in which it is finally to be finished. This operation is called **crossing.** After crossing, the surface should be again gone over softly and carefully, in a direction contrary to the crossing, but in accord with the grain of the wood, taking care that none of the cross brush marks are left visible. Good workmanship demands that the paint should be laid evenly and the brush marks be unobservable. Every coat should be perfectly dry and all dust carefully removed before a succeeding one is applied. For the third coat, oil and turpentine should be used in equal proportions.

99. Final Coat.—The fourth coat may be considered the finishing coat, although a fifth, always with great advantage, is often given. The final coat must not, by any means, be applied unless that immediately preceding it is entirely and uniformly dry, as regards surface; for, if it is glossy in one part and dull in another, it is evident that the absorption of the wood is not stopped, and the third or fourth coat, as the case may be, must be repeated before the finishing coat is put on. The great point in finishing paint work is to keep a good surface, using glass-paper and duster freely, and when

the colour is laid on to cross and re-cross it, finishing with the grain of the wood and using the brush so lightly that it hardly touches the work.

100. **Flatting** is the term given to that method of painting used when it is desired that the dry surface present a flat or dull appearance, without any gloss. The paint used for the first finishing coat should be rather thicker than that employed in other circumstances. Mixed with linseed oil and turpentine, but kept on the oily side, it should be rather darker than the flatting is intended to be. All the coats preceding the flatting must be very evenly spread and smoothed with glass-paper to be perfectly even, otherwise the smallest irregularities will appear in the finished surface, to the injury of that perfectly flat appearance in which lies the real beauty of the work.

The pigment used in flatting consists of white lead, with which the necessary colouring matter is mixed; turpentine alone, with a small quantity of copal varnish, being added. This causes it to bind better. If carefully done, the work will bear one washing without injury to the flatting or the appearance of the dead surfaces. The colour should be rather lighter than that finally required, as it darkens a little while drying. The coat preceding the flatting should be dry, but it should not be absolutely hard, for the flatting should slightly dissolve the surface, so as to become, in a measure, incorporated with it. By this partial incorporation much beauty and durability are obtained. If the previous coat has become quite hard, the flatting will in most cases appear streaky when dry, and is likely to split and peel off.

101. Owing to the special composition of the paint used in flatting, it dries very rapidly, and two, four, or six men may at one time be employed in flatting a wall. In a small room, however, two men are sufficient. A plank laid across step ladders, or trestles, is placed in front of the wall, at about half the distance from the floor to the ceiling. One of the men stands on this platform, while another stands on the floor. The latter commences the work, painting a strip about 18 inches wide and carrying it up as high as he can conveniently reach,

working rapidly and crossing occasionally, so that no brush marks, in any one direction, will be visible, finishing very lightly so that the points of the hairs just skim over the work. The man above proceeds with the operation from the line where the other leaves it, and carries it up to the top of the wall, the first man meanwhile getting on with another strip, both workmen being exceedingly careful that no break occurs, and that the lines at which their work joins is invisible.

102. Stipplers.—Brushes, called **stipplers,** are used to flatten the tint after it is applied. These are broad and flat, and in form resemble a hair brush (Fig. 13). In practice, the stippler is gently dabbed against the wet paint, producing a level grain over the whole surface. These brushes may be obtained in various

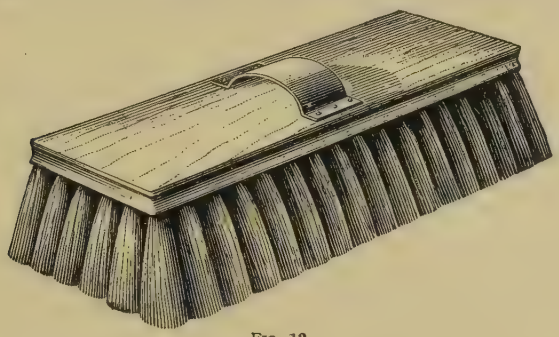

FIG. 13

shapes and sizes, the handles of some being continuous with the back ; in others, fixed as in the illustration. The adoption of either form is, of course, a matter of taste. In flatting a door, the panels must be finished first, and great care taken to carry the paint fully into the edges and corners. Should any brush marks appear at the parts where the work is necessarily in cross directions, they should correspond with the grain of the wood at the joints, as it in reality exists at these points.

APPLICATION TO PLASTER AND CEMENT

103. Interior Plaster.—To paint interior plaster, the first coat should be of white lead mixed with one-eighth part of turpentine, the rest being linseed oil and a small quantity of driers. The

paint should be rather thinner than that used for general purposes, so that it may fully enter into the absorbent surface of the plaster. The next coat also should be thin, so that the plaster may be thoroughly saturated. As this will be but partially absorbed, the third coat should be much thicker, mixing with it spirits of turpentine and some of the colouring matter approaching the future tint of the room. The fourth coat should be thicker still, and mixed with equal parts of oil and spirits of turpentine, together with the dry ingredient. The colour should be darker than that which is to constitute the finishing coat. All these coats should be put on with the greatest attention paid to smoothing, and each allowed to dry before the succeeding coat is applied, besides being well rubbed down with glass-paper. The last coat, preceding the flatting, should not, however, be quite hardened.

104. Exterior Cement or Stucco.—No painting in oil can, with serviceable effect, be done unless the cement or stucco and the brickwork are dry. Besides, it must be remembered that the expansive power of water is such, both in freezing and in evaporation, that when any foreign body obstructs its escape, it immediately assails the obstruction and tends to force off layers of plaster, frequently denuding large sections of wall surface, extremely difficult to cover up. Two or three years are not, in most cases, too long a period for cement to remain unpainted, it being necessary to allow the alkali in the cement to work itself out, otherwise it will throw off whatever is placed on its surface. Ofttimes, however, just so many weeks are reluctantly allowed. It is claimed for some patent liquids that, in spite of the natural properties of bodies, cement washed with these may be immediately painted with oil colours. Instances may, in fact, be cited and experiments adduced, that, at first glance, seemingly contradict, but upon investigation they are found to confirm the laws of nature.

105. There is no better material for priming, or applying as first coat, on cement than boiled oil, turpentine, and red lead, care being taken, in all cases, not to lay it on too thickly, nor in larger quantity than the cement will absorb. It should then be

covered with three or four coats of good white lead colour, each coat being given sufficient time to dry hard. If time permits, two or three days between each coat will not be too long. If the cement is to be finished in some given tint, the ground for the desired tint should be prepared by a slight advance toward it about the third coat of paint.

DRYING PROPERTIES OF PAINTS AND OILS

106. Painting is done with one of two objects in view: to change the natural colour of the surface to which it is applied, or to preserve that surface from the deleterious effects of air, rain, dust, etc. In either case three conditions are to be observed: The paint must be sufficiently fluid to be spread with a brush and yet viscous enough to adhere evenly to the surface without running, besides leaving coats of equal thickness when the surfaces are inclined or even vertical. The applied paint must become hard. After hardening, the paint must adhere firmly to the surface to which it has been applied. Since pure oil hardens, the hardening is plainly the effect of a primary cause independent of the drier.

Experiments demonstrate that white lead and oxide of zinc manifest, in many cases, a drying property found to exist in certain substances that are themselves painted—lead, for instance. The painter desirous of knowing, at least approximately, the length of time required for his work to dry, considers, therefore, all the causes of the drying process, since this process is assisted by several substances having, under certain circumstances, the property of drying paint; for instance, one coat of linseed oil applied upon glass required 17 days, while the same oil, mixed with oxide of antimony, took 26 days to dry. Linseed oil mixed with oxide of antimony and applied upon a cloth painted with white lead, was dry after 14 days. The same oil mixed with the arsenate of protoxide of tin and applied upon a similar cloth was not hard after 60 days. Oak wood appears to possess antidrying property to a high degree, since, in an experiment begun during the month of December, three coats of oil took 159 days to dry, while in an experiment begun during

May, a first coat of linseed oil was not dry on the surface until after 32 days. Poplar seems to be less antidrying than oak, and Norway fir less than poplar. In the experiment for May, just referred to, three coats of linseed oil on Norway fir took 23 days to dry.

Linseed oil has natural drying properties, which are increased by its admixture with white lead and, in certain cases, with oxide of zinc. This mixture does not possess sufficient drying power of itself, so recourse must be had to an addition of patent driers or French powdered driers. It is, at the same time, necessary to consider the nature of the surface painted over, whether it is a first, second, or third coat ; also, the temperature of the air, the light, etc.

107. Drying oil, boiled with litharge or manganese, loses some of its value because it may be dispensed with in the second and third coats and even in the first, when natural drying is aided by the temperature. Pigments themselves may, moreover, act as substitutes for it, as in the case of light colours, which are altered by browns or yellows. Linseed oil, exposed to air and light, becomes drying and loses its colour, and may therefore be employed with white lead or zinc white without impairing the whiteness of either. The association of oxide of zinc with carbonate of zinc makes it possible to dispense with a drier and presents a ready way of avoiding the inconvenience of coloured driers.

REPAINTING AND CLEANING

108. **Old Work.**—In commencing to repaint old work, the surface should first be gone over with the stopping knife and all excrescences removed. It should then be rubbed with pumice stone and soda water, the greasy parts being washed or *pickled* with soda water, or *strong stuff* as it is called, and well scraped and rubbed with pumice stone.

109. **Cleaning old paint** may be effected by washing it with soda water. If the surface is very greasy, it may be treated with fresh quicklime mixed in water, washed off and reapplied until the grease is entirely removed.

110. Removing Old Paint.—Dissolve 2 ounces of soft soap and 4 ounces of potash in boiling water ; add $\frac{1}{2}$ pound of quicklime ; apply hot and leave from 12 to 24 hours. This will enable the old paint to be washed off with hot water, after which care should be taken to thoroughly cleanse the woodwork of the solution, as if any is allowed to remain it will destroy any new paint that is applied.

Old paint can be burnt off by means of a blow lamp. This method must be adopted when many coats have to be removed or the paint is very blistered or cracked. Parts from which the paint has been entirely removed, and decayed patches, must be primed and stopped before the first coat of new paint is applied. The quality of the next coat, which will be the ground or first-finishing coat, depends on the manner in which the work is to be finished. A general rule for finishing in oil is that the under or first-finishing coat should be in oil. All turpentine grounds must have a little oil mixed with them, and all under coats, except the priming, or first coat, in new work, have a small quantity of turpentine added.

PAINTING AND DECORATING

(PART 2)

DECORATION

INTRODUCTION

1. The study of decoration demands something more than an elementary knowledge of the art: it demands a careful study of all masterpieces. This will broaden and develop the originality of the decorator, to whom nothing is more important than a keen appreciation of the value of colour, good work being frequently marred by an injudicious arrangement of tints. Much time is often lost in attempts to match the colour of the wallpaper with the painting of the woodwork. The true artist, instead of matching the paper, ascertains the most appropriate contrasting colours, for the harmony of contrasts is the key of successful decoration.

2. Colour Contrasts.—A useful table of direct colour contrasts is the following:

Blue contrasts with orange;
Blue green contrasts with red orange;
Green contrasts with red;
Yellow green contrasts with red purple;
Yellow contrasts with purple;
Yellow orange contrasts with blue purple.

In the decoration of a cornice or frieze, the general tone of whose colour has been decided on, the contrasting colours for the various members may be, by this table, readily found, and

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the massing or blurring of the parts easily avoided. The style of contrast depends, of course, on the design and purpose of the room. An inside room, to which sunlight rarely finds its way, requires different treatment from a bright airy room on the sunny side of the house. The ground colour of any wallpaper being noted, reference to the list will at once give the colour demanded by the figures on the paper or the woodwork. Thus, a blue-green ground requires a reddish-orange tint, the effect being to define the boundary of wall and cornice with elegance and distinctness. When tinting a cornice, care should be taken that the colours, as they approach the ceiling, recede from the eye, an effect attained by reducing the strength of the colours employed until that which on the lower members is a distinct colour becomes at the top a mere tint, preserving only the original tone. Attention to this point prevents the ceiling from appearing too low. Decoration of any kind tends to give this effect of lowness to the ceiling ; when, therefore, the light tints are kept in accord with the general colour of the room itself, the more pleasing, because less obtrusive, is the effect.

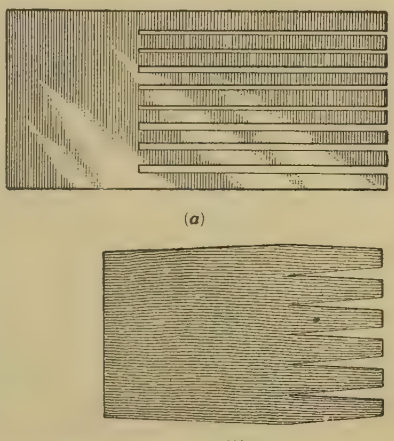
GRAINING AND MARBLING

3. Definition.—Graining is the term applied to a method of finishing painted surfaces in which the last coat is made to imitate the grain or fibres of the wood. Its use is extensive for genuine hardwood finishings, such as mahogany and oak, but it cannot always be used, on account of cost. It requires much skill and knowledge of the woods to be imitated and gives a good appearance to the room. Graining is done with the same brushes used in general house painting, except for the implements required for the final coat.

TOOLS USED IN GRAINING

4. Graining combs, shown in Fig. 1 (*a*), (*b*), and (*c*), are tools, usually made of steel, although that at (*b*) is often made of leather, with which the straight and wavy grain of certain kinds of wood is imitated. The paint, of the proper colour for the

grain, is laid on the surface with a pound brush, and then immediately scraped with the graining comb, which removes the applied colour in streaks, and leaves a fine, threadlike grain over the ground or body colour, which must be dry before the graining is commenced. Graining combs are usually sold in sets of twelve, three each 1, 2, 3, and 4 inches wide, and vary in width and coarseness of teeth, as in Fig. 1, though single combs may also be obtained.



(*a*)

(*b*)

(*c*)

FIG. 1

5. The Veining Horn. The **veining horn,** shown in Fig. 2, is used in the same manner as the comb, but only when the graining is to be in broad veins instead of a series of fine parallel lines. The veining horn is made of a piece of celluloid or horn, and, after being covered with a piece of rag, is drawn along the freshly painted surface, to remove the colour and expose the body colour or ground. The veining horn is not used by an expert, as the thumbnail of the right hand can be trained to do the wiping out more successfully.

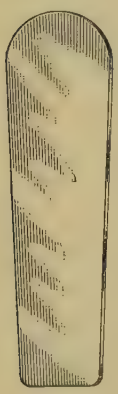


FIG. 2

6. Pencils.—A number of different-sized camel-hair brushes, called **pencils,** are used to mark the grain in certain woods.

One size only of this variety of brushes is shown in Fig. 3. These are usually mounted or bound in the small end of a goose quill, while in the large end a wooden handle is inserted. The brushes belonging to this class are called pencils because their purpose is to produce lines or stripes. In this respect they differ from ordinary brushes which are intended to spread the colour over a considerable surface. They are always made of soft hair, such as sable or camel hair, and are either pointed on the end, as in Fig. 3, or cut off square as in Fig. 4, which shows an implement called a **pencil overgrainer**. This device consists of a number of camel-hair pencils which are mounted on a broad wooden handle, and used to mark the parallel grain of various woods.

FIG. 3

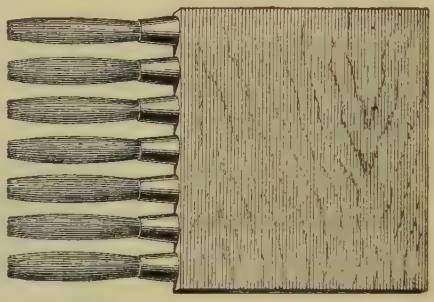


FIG. 4

7. The Oak Overgrainer.—The **oak overgrainer**, shown in Fig. 5, is used in the same manner as the pencil overgrainer, except that the hair of the brush is divided by the hand into

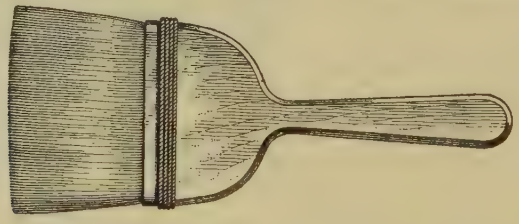


FIG. 5

a series of small tufts, after the brush has been charged, and the bristles so parted are drawn over the surface to be grained, thereby producing the effect of an irregular-grained surface peculiar to oak, ash, and similar woods.

8. The Mottler.—The **mottler,** shown in Fig. 6, is used to produce that peculiar mottled appearance prevalent in several woods and for wiping out the undergrain. It is used dry and applied to the painted surface with short quick strokes, to

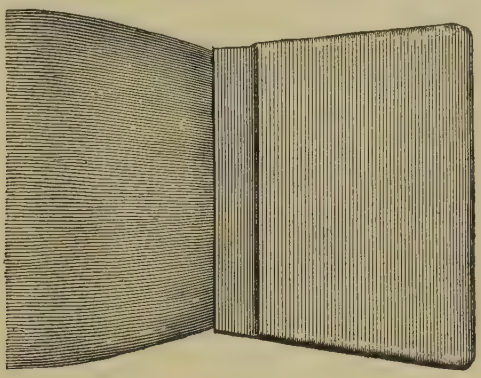


FIG. 6

remove and replace little particles of colour, thereby producing the soft, mottled, or graded effect of one vein running into another.

9. The Badger Softener.—The **badger softener,** shown in Fig. 7, is used to remove any coarseness caused by wiping out, and to soften the edge of the parallel veins and take away the appearance of a hard line or stripe produced by the use of the pencil, overgrainer, veining horn, or comb. While the foregoing are the tools principally used, a good workman will obtain many effects in the imitation of woods by the dexterous use of his finger or thumb. There have been introduced rollers that have patterns engraved on them, which are repeated as they are rolled over the wet paint. The only one that should be used in good work is that which forms the small black lines found in oak ; the others do not give a good imitation of natural effects.

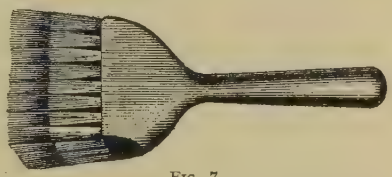


FIG. 7

GRAINING

10. Graining is, as has already been stated, the imitation of the natural veining and curl of woods, and needs, in spite of anything stated to the contrary, a degree of taste, observation, and dexterity of hand, placing this art far in rank above that of plain painting. For their faithful production, special attention must be given to the structure, growth, and ornamental character of various woods. A useful collection of wood specimens may, for this purpose, be obtained by acquiring a few feet of veneers, cut from each of several woods. Glued on common pine plank. French polished, and oil rubbed, these veneers make an excellent set of grainer's samples. The plain painter having previously given the new wood three or, sometimes, four coats of paint, the grainer commences his work by laying the graining ground, differing in composition according to the wood to be reproduced.

A number of examples of wood graining are given, but it must be understood that the markings of any wood can be imitated in a similar manner to those described, and it would be good practice for one to obtain a good sample piece of wood, which has been polished up carefully, and try to imitate its markings.

11. Wainscot, or Middle, Oak.—Fig. 8 shows a piece of graining in imitation of wainscot, or middle, oak. This illustration has been photographed from actual work and gives an idea of the state of perfection to which the grainer's art has been brought. The ground for this sample should be mixed with white lead, raw sienna, and a little umber, and applied to the wood and left until ready to receive the finishing coats or graining. Then mix burnt umber with a little raw sienna and driers, and reduce the colour with oil and turpentine until the proper tone is reached. Lay this colour evenly over the board, and with the 4-inch stout steel comb, comb down the colour with even pressure; then take the next size comb and draw it across the last combing at an angle of about 95°, after which the finest comb should be drawn straight down. Now, with the veining horn and rag or the thumbnail, wipe away the wet colour as necessary, leaving the ground colour showing and so form the design usually found

Fig. 8 § 41 5169

Fig. 9

§ 41 5169

Fig. 10 § 41 5169

in oak, softening the hard edges of colour with a piece of cloth folded up quite tightly. After the whole surface is thoroughly dry, sponge it down carefully with beer and whitening, which will prevent *cissing*. In cissing the water colour runs off from the somewhat greasy or oily surface of the paint to which it is applied. To finish the specimen completely, the overgraining must be done. For this, mix a little Vandyke brown in water or beer and, dipping the oak overgrainer into it, draw the overgrainer down lightly over the work and soften it with a badger brush, after which, and when dry, the work can be varnished.

12. Dark, or Church, Oak.—For dark, or church, oak, the work is prepared as for wainscot oak, but the finishing is somewhat different. The dark veins peculiar to this type of oak must be put on by means of one of the pencils. The work is also rolled to form the small black marks always showing in the grain, the roller being charged with a black colour formed from vegetable black mixed with gold size thinned with turpentine.

13. Fumed Oak.—The ground for fumed oak is prepared in a similar manner to that for wainscot oak, but for the graining colour raw umber, raw sienna, Prussian blue, and driers must be mixed and reduced to the required tone by the addition of linseed oil and turpentine. The design is worked exactly like that for wainscot oak; an example of actual work is shown in Fig. 9.

14. Knotted, or Gnarled, Oak.—For knotted, or gnarled, oak, the ground work is prepared in a similar manner to that for wainscot oak, but it requires rather a fuller tone of colour. The graining colour is made by mixing burnt umber with a little black to which is added driers and linseed oil and turpentine. In Fig. 10 is shown a sample of graining to imitate knotted oak. To obtain the figure in the grain, the graining colour should be laid on so as to form the design roughly and the darker colour added as necessary to form the bunches of knots. After this has been done, these bunches should be worked round with the thumbnail or veining horn, so as to join them with the straight-grained wood between them, and leave them in groups to look as

natural as possible. The spaces between the bunches of knots can be worked upon in a similar manner to that for wainscot oak, and all that then must be done to complete the work is to overgrain and varnish it.

15. Bird's-Eye Maple.—An example of graining to imitate bird's-eye maple is shown in Fig. 11. To execute this, the ground is composed of white lead mixed with sufficient vermilion to neutralize the blue tinge of the white lead, but not to give it a pink tint. The mixture must be rather oily, that is, it must contain a good quantity of oil, in order that the graining colour may not be as much absorbed as if the surface were flatted, or coated with colour mixed with turpentine. In order that the graining colours usually mixed with beer may adhere to the ground that has been painted in oil, it is necessary to prepare the surface by passing over it a sponge moistened with beer and rubbed on dry whitening; when this is dry, the distemper, or beer-mixed colour, will work freely over the oil and adhere to it. This prevents cissing. The graining colour, which is ground in beer instead of oil, consists of Vandyke brown, mixed with 3 parts of whitening and drop black, according to the tint required. With a tool, the colour is laid over the whole panel and worked to a level with the mottler. Then lights are taken out from the still wet colour by dabbing the surface with the mottler, and at the same time drawing it along, by which means the colour is, in certain places, removed. Soften the whole, with the brush called the *softener*, so set as to spread outwards and to be rapidly as well as lightly drawn over the work, without leaving any brush marks. Next, with a thinner mottler, work round the edges of the lights, giving a pointed tendency to their forms, likewise filling in the finer work in the darker spaces. When this has again been softened, use the small brush called a *dotter* and from the edge of the lights form the birds' eyes by pushing the colour along. The overgraining needs some burnt sienna and whitening mixed with beer. With a sable pencil trace a design similar to the sap in heart of oak. Fill in the rest with a long-hair overgrainer separated with a comb, then fold up tightly a thin piece of cloth soaked in the

Fig. 12

§ 41 5169

FIG. 13 § 41 5169

burnt-sienna liquid and form a small hole and ring up the birds' eyes ; this will give a very woody effect.

16. Satin Wood.—In Fig. 12 is shown an example of graining to imitate satin wood. The ground is composed of white lead, just tinted with chrome yellow, raw sienna, and yellow ochre ; cissing is prevented with whitening and beer. The graining colours are made of raw sienna and a little Vandyke brown, and the work is rubbed in level with a tool and the mottler. A rather coarse sponge is then wetted with beer and drawn down the work, so as to leave rather broad streaks running in a slightly wavy or oblique direction, and softened with the badger softener. Next, with a clean, moist, camel-hair mottler, the edges of the streaks are worked down with a jerky movement, so as to give that varied and fanciful appearance so much admired in the natural wood.

The overgraining colour is mixed in beer, using the same colour that the work is grained with. The heart must be done with a small sable pencil, the work being slightly brushed up with the badger. The rest of the overgraining is done with a sable tube overgrainer, or with a sable flat overgrainer, the hairs of which have been separated with a comb.

17. Mahogany.—There are many shades of mahogany. The following are, however, the colours generally used and those which obtained the results shown in Fig. 13, where an example of mahogany graining is given. They can, however, be varied according to taste, or darkened by the addition of pigments of a deeper hue. The ground colour is Venetian red, cissing being prevented as before with whitening and beer. The graining colour is made of Vandyke brown and brown lake mixed in water to suit the ground.

The colour, which is mixed with beer, is rubbed in dark with the tool and mottler ; then, with a clean and moist camel-hair mottler, it is carried out according to the method described for satinwood. To produce a feather or curl, the colour is drawn with the badger from the side, toward the middle of the panel. Much taste and skill are required in the next process, which consists in working up the feather or curl. This is done

by gathering up, as it were, the grain from each side to culminate in the middle, working toward a point which must become more and more elongated. The process and effect are difficult to describe, but the workman is advised to adopt nature as his model. When once he understands the result to be obtained and the means at his disposal, he will, with a small amount of perseverance and industry, soon discover the method of working by which he may best achieve his purpose. Excepting that the pattern is smaller, the curl and mottling of satinwood are so much like those of mahogany that the same manipulative process can be adopted for both.

The overgraining colour in mahogany is made of Vandyke brown, with a little brown lake. The tools are the hog-hair or sable overgrainer and a small overgraining comb. In a curl or feather, the overgraining must follow the direction of the curl, rising from the centre and becoming gradually more pointed until it is lost in the general mottling of the wood ; if the wood is to be mottled only, the overgraining must run in the direction of the mottling. Should the work, when thus far finished, be found too light in colour, or not sufficiently rich, it may be varnished. When this is dry, a mixture of brown lake and Vandyke brown, or Prussian blue to match work, may be rubbed over it until the required tint is obtained. The whole is softened and, when dry, again varnished.

18. Walnut.—In Fig. 14 is shown the way to finish the undergrain for imitating English walnut, while in Fig. 15 is shown the graining completed by the addition of the overgrain. Figs. 16 and 17 similarly show the undergrain and finished imitation of American walnut. The ground for walnut is mixed raw sienna and a small quantity of burnt sienna, burnt umber, and white lead ; the work is then sponged in with whitening and water. The graining colour is Vandyke brown and raw sienna mixed with water, rubbed in with a tool and mottler, then mottled in the manner described in the process for maple, and afterwards well softened. When this is dry, commence the overgraining. The colour for this process is Vandyke brown and drop black, mixed with beer.

FIG. 14 § 41 5169

FIG. 15 § 41 5169

FIG. 16

§ 11 5169

FIG. 17 § 41 5169

With a light tint of this mixture, just sufficient to show, using the divided or walnut overgrainer, sketch the general design of the grain and soften by pushing the grain outwards. With a darker shade of the same colour, work up the graining to the required design, softening continually during work. Superior work is now varnished and, when dry, the whole is glazed with Vandyke brown and water, then mottled and well softened, after which treatment it is again varnished.

MARBLING

19. Definition.—Marbling is the finishing of painted surfaces to imitate marble. It can only be done successfully by one who has made a careful study of the grain and markings of, at least, the principal kinds of marble in use.

20. Sienna Marble.—In Fig. 18 is shown an example of marbling, or imitation sienna marble, the ground for which is white lead. The work is evenly gone over with white paint tinted with raw sienna mixed with equal quantities of turpentine and oil. After this, three tints are mixed, one consisting of raw sienna, and the others of burnt sienna and vermilion mixed with equal quantities of oil and turpentine. With separate tools, dab patches on the white paint while yet wet, and with a brush soften the patches together, great care being taken not to allow the red tint to be too dominant. On a palette, at the side of which is placed a palette cup containing turpentine, place a small quantity of blue black; then, with a sable pencil dipped in turpentine and blue black, trace the design or vein on the wet work, and soften; work up the veins further with more blue black and a fitch; after which soften lightly. When dry, put in the whites, with white lead mixed with turpentine, using a sable pencil, subsequently softening the work with a badger; or while the work is wet the whites can be wiped out by placing a piece of rag over the thumb. For good work, glaze over all when dry with a very thin wash of the starting colour and, when the paints are quite hard, apply a light varnish.

21. Egyptian Green Marble.—In Fig. 19 is shown an illustration of marbling to imitate the Egyptian green marble. To imitate this, it is necessary to mix with linseed oil, turpentine, and driers, two separate pots of colour, one containing middle Brunswick green and the other white lead. After having carefully prepared the black ground, the colours are laid on with good duck's-wing feathers, the green design being first obtained roughly, after which the white is put in. The veins should be carefully worked in with a sable pencil and white colour, softening off the edges with the badger brush, and great care should be taken to avoid making the veining look too mechanical. If a small quantity of vermilion is now worked in, the whole can be allowed to dry preparatory to varnishing.

22. Irish Green Marble.—In Fig. 20 is shown an illustration of Irish green marble, which is worked up in a very similar manner to the Egyptian green.

23. Black and Gold Marble.—In Fig. 21 is shown a marbled imitation of black and gold marble. The ground being black, paint the large spots, from which the fibrous veins run, with yellow ochre and white, the brightness of which must be heightened by the addition of a little Venetian red. The masses must be dabbed with freedom upon the ground, with a brush full of colour, and, while quite wet, threads drawn from them in all directions, some, of course, larger and thicker than others. To vary the work and give an effect like this marble, fill the top part of the pencil with red and the other half with the ochre colour, and here and there press the pencil down. This requires some practice, but is worth the trouble and time necessary to master it. White veins, with small threads attached, crossing each other and the yellow veins in all directions, are sometimes seen running in the deepest parts of the black. Care must be taken that the threads are connected with, and run in the same direction as, the thicker veins. If the ground is properly prepared, the yellow and white veins may both be painted at once in oil colour. Most beautiful imitations of the finest specimens of this marble are produced by spreading a leaf or two of gold in any part of the work where gold and silver leaf, and where

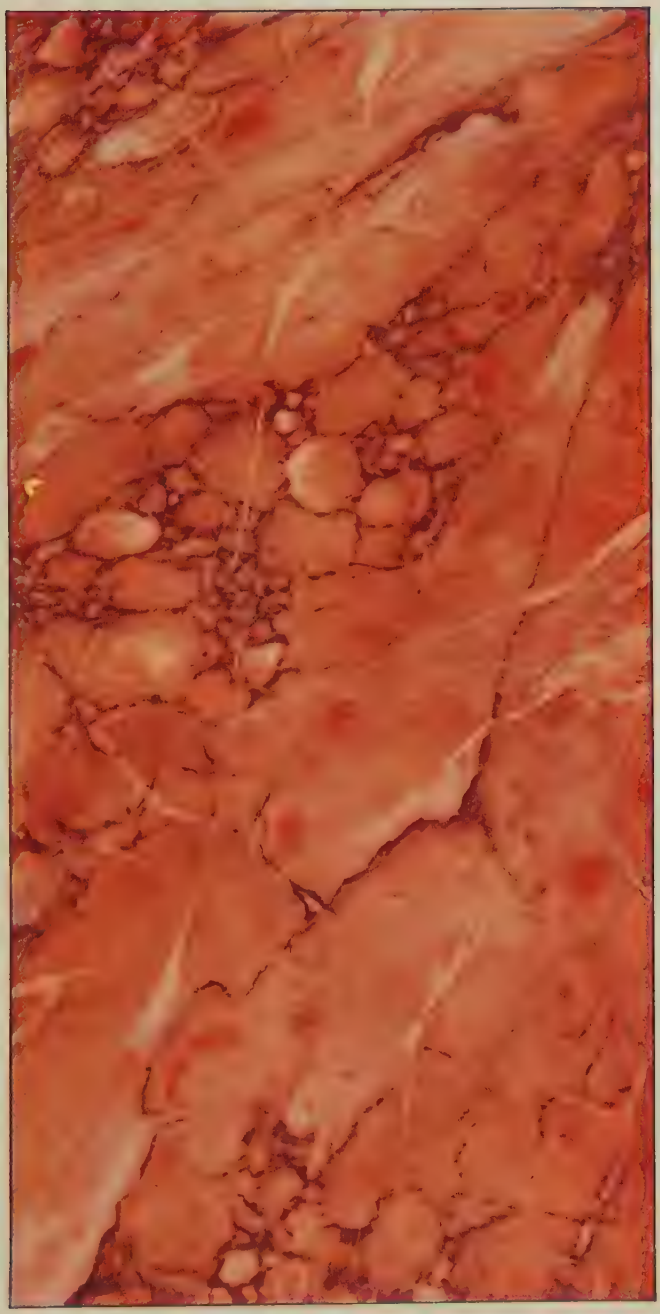


Fig. 18

§ 41 5169

Fig. 19 [illegible]

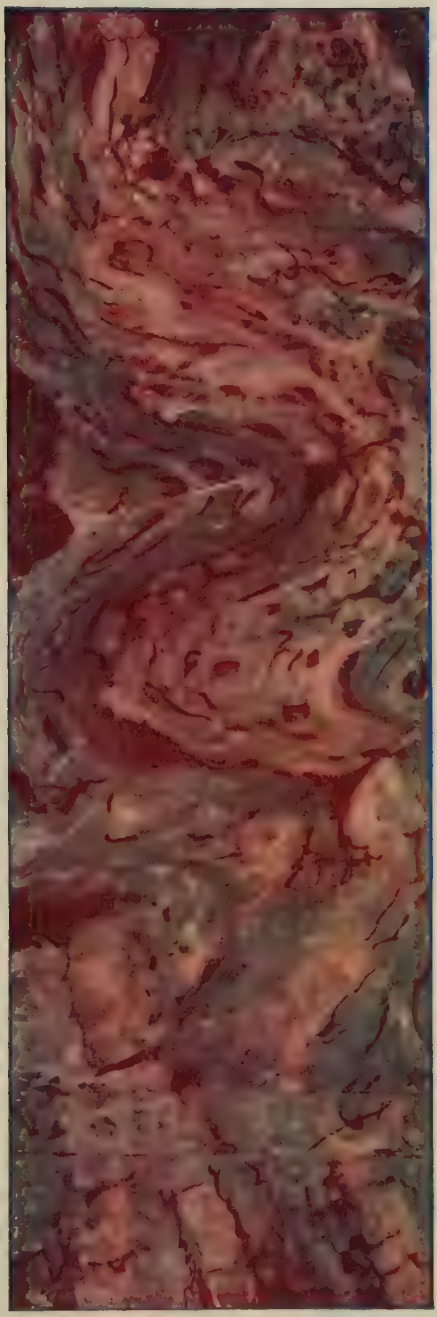


FIG. 20 § 41 5169

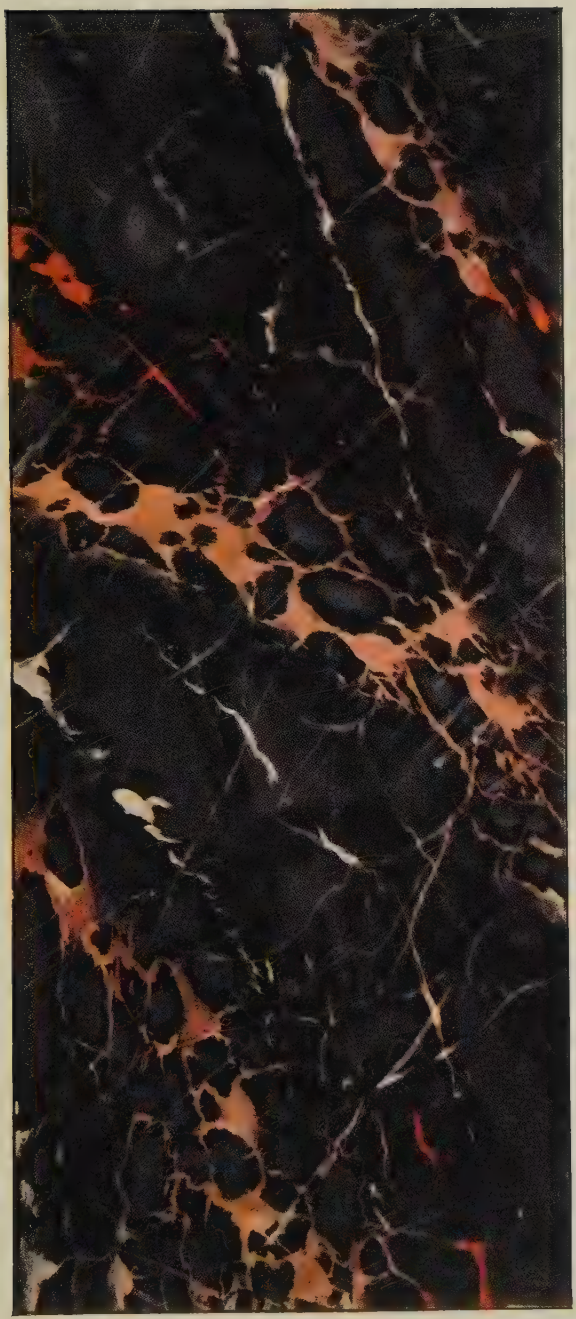


Fig. 21

§ 41 5169

white veins, are intended to run. The black ground is then rather thickly painted over the whole surface, covering the gold and silver leaf. After the colour has been on a short time, take a piece of rag over the thumb and draw this colour in small, reticulated veins from off the gold and silver leaf. The metal then shows in fine lines. The larger masses should be wiped off with a piece of ordinary wash-leather over the point of the thumb or a piece of wood. When the black is dry, the yellow and white veins should be painted as before directed, and drawn over the gold and silver, which by this means will, with great brilliancy, show through them. Otherwise, paint the ground in deep ivory black ; put on the veins in white, yellow ochre, burnt and raw sienna, using a camel-hair brush ; glaze the spaces between the veins with a thin coat of grey or white, over which pass a few white veins. The veins may also be put in with gold leaf.

STENCILLING

24. Stencil Plates.—A stencil plate is a perforated pattern, usually consisting of a sheet of prepared paper or very thin metal, through which the design is cut as shown in Fig. 22, where *a* is the plate in which the pattern *b* is perforated. Small connecting pieces *c*, called ties, are left in when the pattern is cut out, to secure the various parts in their respective positions.

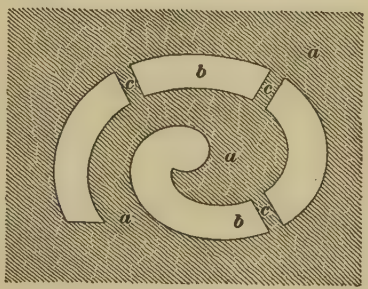


Fig. 22

25. Cutting Stencils.—The parts of the design possessing a scroll formation should be carefully cut with a sharp knife upon a piece of sheet iron or plate glass. Any of the knives shown in Fig. 23 may be used for the work, but the form of blade shown at (*a*) is the one most frequently employed, particularly for straight line work. The blade shown at (*b*) is stronger at

the point, and may be used for either straight or curved work, though when the curves are very small, the blade shown at (*c*) should be used. This last is also desirable where very acute angles are to be cut out, as it admits of being worked very closely to the desired lines.

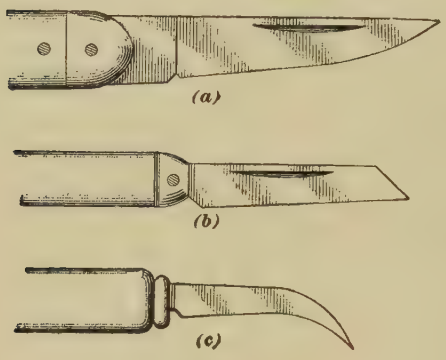


Fig. 23

26. Making the Pattern.—The plate is laid over the surface to be decorated, and a short stiff brush, as shown in Fig. 24, charged with a little colour, is used to draw the pattern on the wall, through the openings *b*. Small unpainted spaces are thereby left at the ties, which must be filled in by hand after the stencil is removed, unless the style of pattern is varied to make these ties form part of the design. Fig. 25 shows the same scroll, with the different sections outlined and

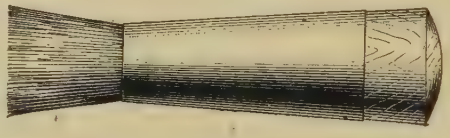


Fig. 24

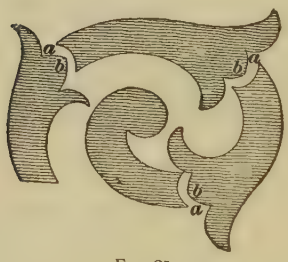


Fig. 25

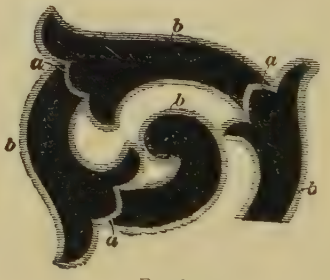


Fig. 26

filled in to a foliated form where the ties exist. The ties *a* are, in this case, an advantage to the pattern, helping to outline the central leaf *b* of the foliated design.

Fig. 26 is an elaboration of the stencilled pattern in Fig. 25,

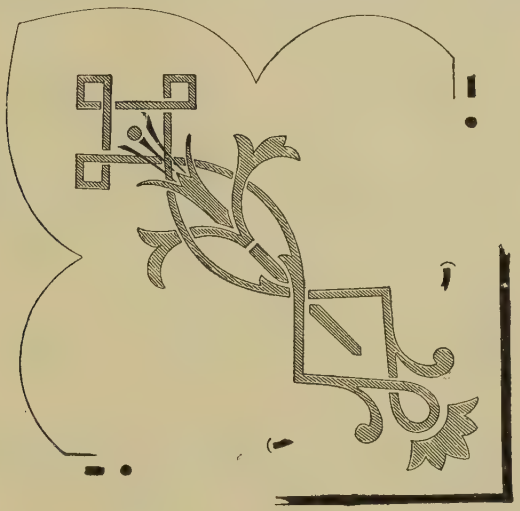


Fig. 27

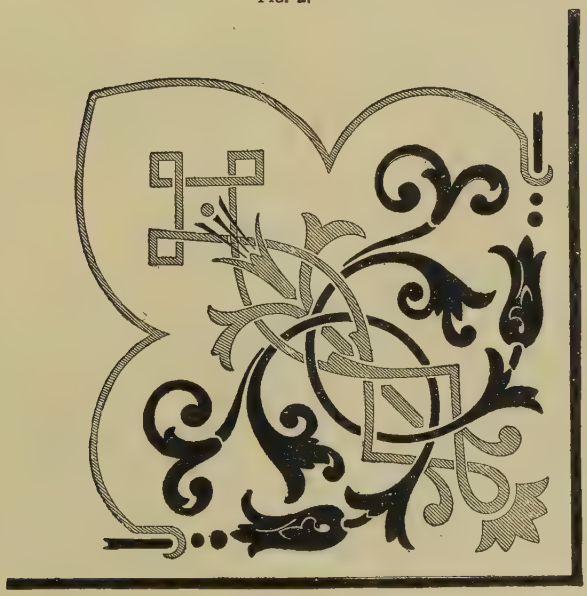


Fig. 28

in which the spaces *a* left by the ties are painted in a contrasting

colour, carried round the entire figure, as shown at *b*. From this simple example it may be seen that the introduction of a more ornamental scroll is really less likely to take extra time

Fig. 29

than a perfectly plain one. The value of this arrangement is, of course, more apparent in the application of rapid decoration to

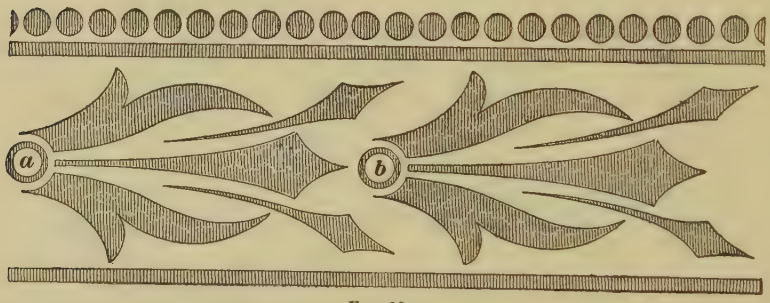


Fig. 30

ceilings and work further removed from the eye than the walls or dado of the room, especially when time is given to retouching the

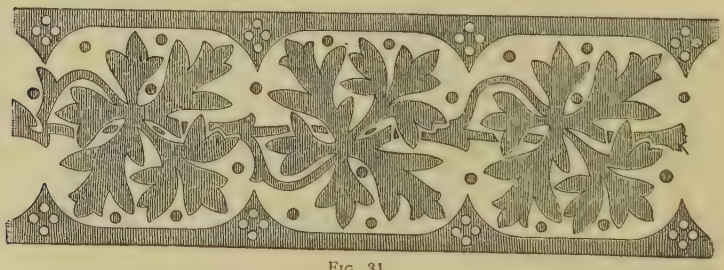


Fig. 31

work and removing some of the raggedness inseparable from the use of the stencil plate.

27. The panels of doors admit of such decorative effect as

Fig. 32

the judicious use of the lining fitch and straightedge for borders and mouldings may produce, with a stencilled design in the corners. Fig. 27 shows a stencil which may be used as a corner design by itself in one colour, or combined with a contrasting colour, executed through another stencil, as shown in Fig. 28. Here the lighter portion is still stencilled on the surface with the stencil plate used in Fig. 27, while the darker colour is laid over it, after the former has dried.

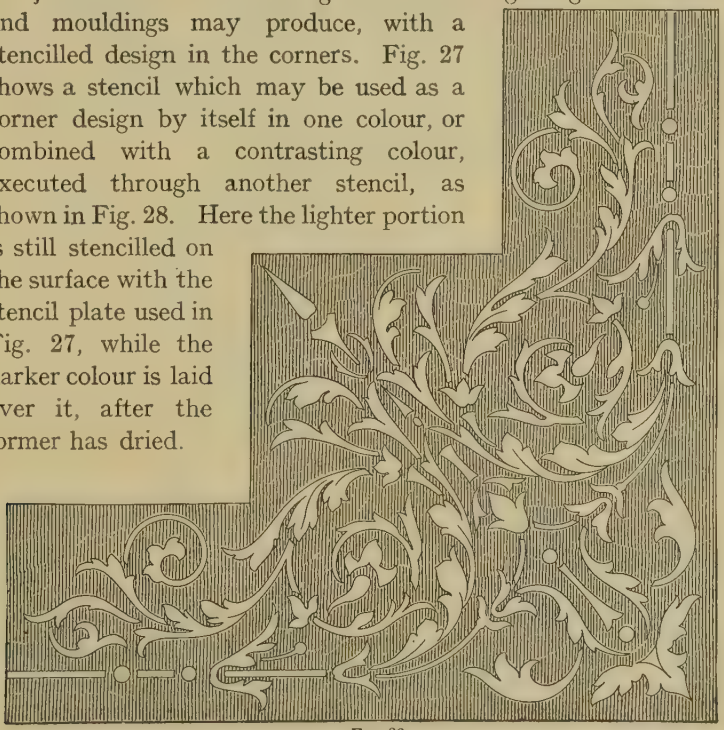


Fig. 33

28. Borders and Centres.—Fig. 29 shows a conventionalized maple-leaf pattern, which may be used as a stencilled border design, while Fig. 30 shows a still more conventional pattern of foliage, which is a repetition of the same lines between *a* and *b*.

Where a stencil pattern is repeated at regular intervals as in Fig. 30, it is always desirable to have some mark cut through the stencil plate by means of which the plate may be set and adjusted when moved to its next position ; otherwise, there is the likelihood of unequal spacing of details and the irregular

Fig. 34

arrangement of parts. This is especially the case where the ties form a part of the design and the irregular spacing would cause them to be of varying widths.

29. In Fig. 31 is shown a more complicated design for a border stencil where some of the ties are left to outline certain details of the pattern, while the others are all touched out to form a continuous figure. Fig. 32 shows a design for a stencilled cresting, which may be used to advantage in some borders. It is composed of various foliated forms, more or less conventionalized, to suit the pattern and purpose.

30. Corners.—Fig. 33 shows a design for a corner piece where this conventionalized foliage is carried to excess, as was typical of the later Renaissance period, but is a style of ornament lending itself most readily to the work of the stenciller. Figs. 34 and 35 show two patterns for centre pieces which may be used on a ceiling or the face of a pilaster. Fig. 34 is executed in one colour, with only one stencil plate, while Fig. 35 is prepared by first stencilling the lighter tint, and then applying the heavier shade on top of it with another stencil, as described in connection with Fig. 28. The flexibility of the stencil plate renders its application to curved just as easy as to flat surfaces, unless the curve exists in more than one direction. Fig. 36 shows a section of plaster cornice, the cove of which is appropriately decorated with a repeated stencil pattern, as shown at *a*, while the lower bead moulding *b* is stencilled at regular intervals with geometrical figures. Fig. 37 shows another pattern, frequently used in the coves of cornices, and is somewhat more appropriate for deep coves than is the ornament shown in Fig. 36, being bolder in design and better suited to a dimly lighted position.

Fig. 35

31. Panels, Walls, Etc.—In Fig. 38 is shown a stencil design executed with two patterns, one to draw the leafwork and the other to form the stems and tendrils in the darker shade. This ornament is appropriate for the end of a panel, the border lines of which are shown in the cut. Fig. 39 shows a scheme for the stencil decoration of a pilaster, the ground of the pilaster being

FIG. 36

painted a dark colour, and the stencil work overlaid in a lighter contrasting shade. Three sets of stencils are necessary for this design, one to draw the details of the dado panel, as shown at *a*; another to form each of the running borders, as seen at *b* and *d*,

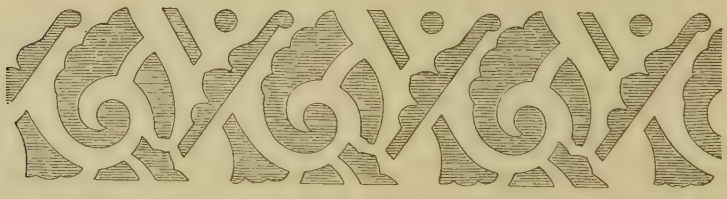


FIG. 37

which may be made in one stencil, if the pilaster is not too wide, or repeated in sections if more convenient. The other two stencils are required at *c* and *e*, and may each be made in one piece, or divided through the centre and applied to each side of the centre line.

When stencil work is applied to ceiling decoration, the stencil plates must sometimes be unusually large or divided into a

Fig. 38

number of sections. Fig. 40 shows the corner of a ceiling design which may be stencilled in one colour on a dark ground, or in two contrasting colours, as shown. Fig. 41 illustrates the treatment of the side walls and frieze and the door panels of a simple room, where the stencil and brush are the only tools used, except the straightedge, where ruled lines are required. The frieze design may be executed in a monotint or stencilled, in two or more colours, appropriate to the conventional forms depicted.

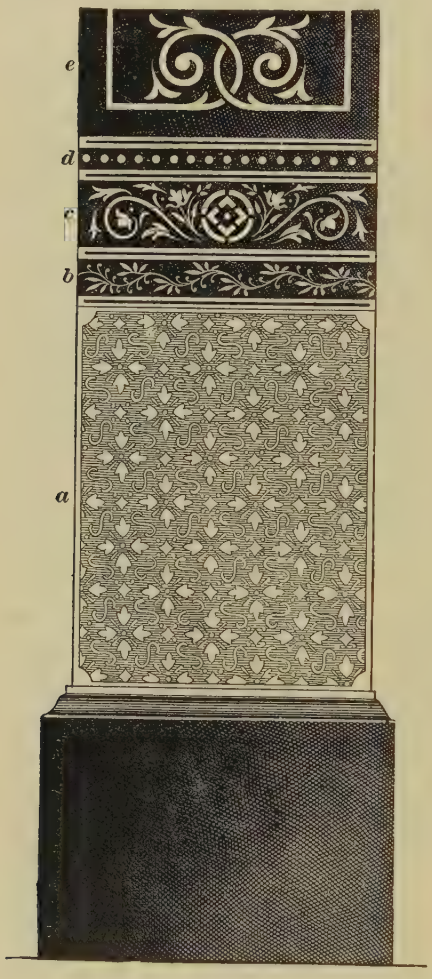


Fig. 39

32. Stencilled Inlay. A unique effect may be produced by the introduction of imitation inlaid work on the ordinary graining of a door and dado. The method is simple and capable of infinite variations. Figs. 27 and 28 show the corner of a panel so treated, and will, if worked out on the principles laid down, be found a satisfactory addition to the usual decorative work. The door may be grained, preferably in imitation of satinwood for the panels, and with oak stiles, or the whole may be grained in plain oak, after which the first necessary step is to prepare a stencil. Having prepared the stencil, thoroughly clean

the panel by wiping it with wash-leather to remove any grease, etc., from contact with the colour now to be used. The panels should have been previously varnished. If the inlay is to imitate walnut, take equal parts of Vandyke brown, burnt sienna, and a sufficient quantity of lake to impart warmth of colour. These must be ground in water, and used with sufficient stale beer to render the colour workable. Coat the panel entirely, and with a hog-hair mottler vary the tints by taking out some portion before it dries, softening the whole with a badger-hair brush. When thoroughly dry, the panel is ready for the stencil.

The centre of the panel and the margin may be marked out in chalk, lines

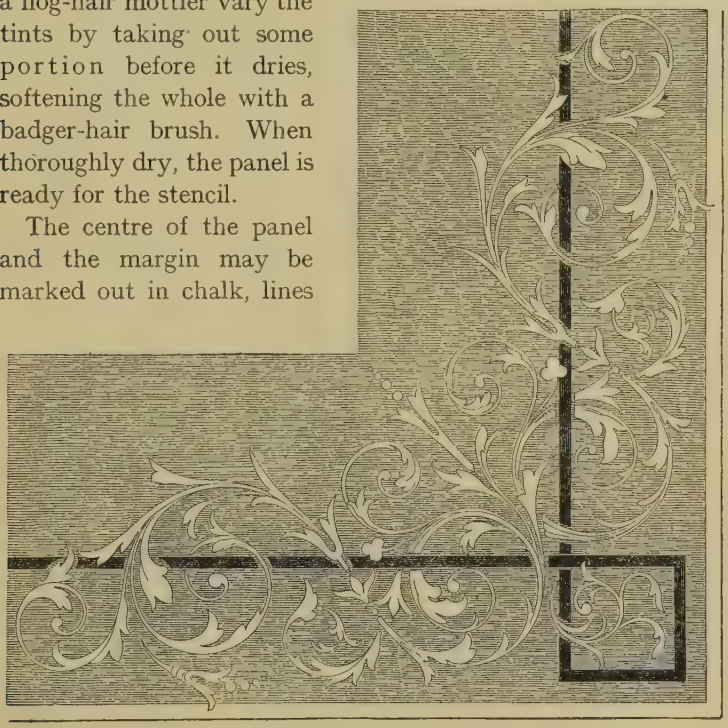


Fig. 40

being struck in the ordinary manner by holding a piece of twine or strong cotton, on which chalk has previously been rubbed, from the marked points, then snapping the line by pulling it from the surface of the panel, it will leave its impress on the work. This method is better than that of lining with the straightedge.

33. The pattern should next be stencilled on with Japan gold size, slightly reduced with turpentine, taking care to use

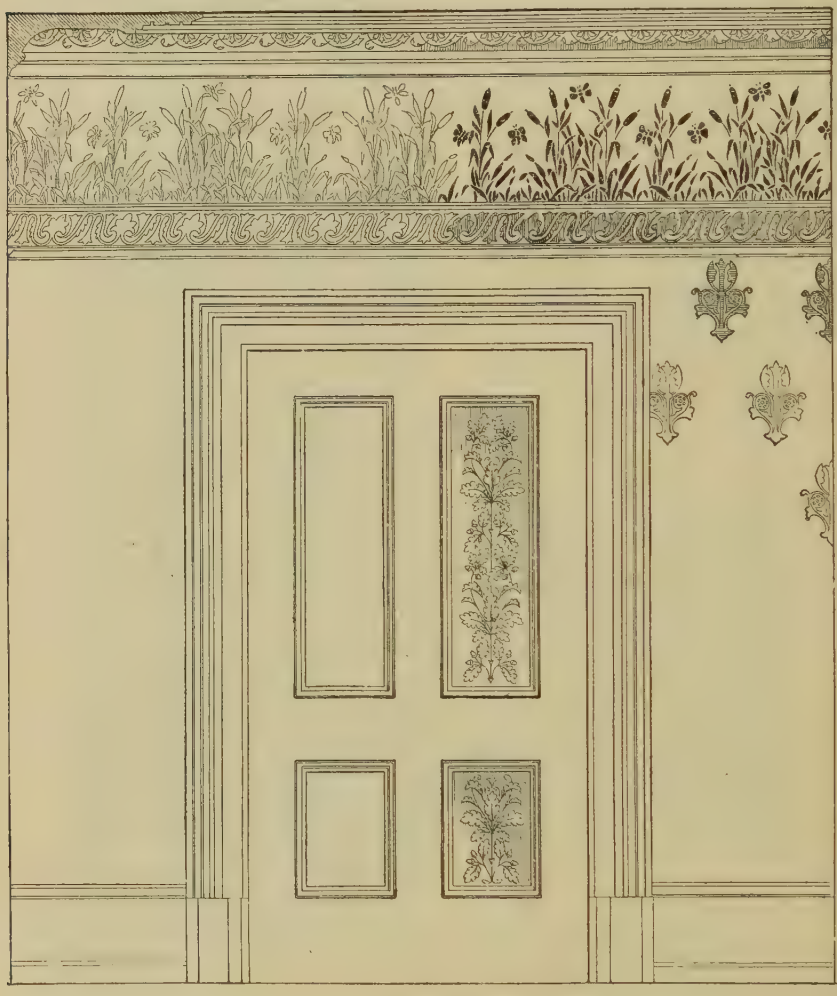


Fig. 41

it as sparingly as possible to prevent spreading or the formation of a ragged edge on the design. The top, bottom, and centre scrolls having been stencilled they should be connected by

drawing the lines in the same medium, using for the purpose an angle fitch and the straightedge. In about an hour the panel will be ready to bear washing off, which should be done with a soft sponge, carefully removing the whole of the distemper and drying the panel with a chamois leather, leaving the pattern as defined by the gold size. This is usually sufficient for all ordinary purposes, but an additional effect is imparted by pencilling round the scroll with a cream colour tint, as shown in Fig. 26. This latter, it will be noticed, effectually removes the necessity of taking out ties, uniting the parts as in a real inlay. Tulip wood may be represented between this line and the moulding, by using damp lake, with beer as hitherto, and carefully cutting into the line with Japan gold size, washing off the surplus colour when the size is quite hard. The mouldings, architraves, etc., may be darkened with the walnut colour to correspond with the panels.

34. Where more than one kind of wood is to be imitated, it is necessary to omit the gold size on those parts where the different imitations are required. After washing off the size, coat the parts with water colour of the proper tint and proceed as before, repeating the process with every fresh colour. In this way, tulip, walnut, mahogany, pollard oak, cedar, rose, or, in fact, the required imitation of any wood, may be introduced at the designer's discretion. The greatest care must be taken, in the process of imitating inlaid decoration, that the varnish is thoroughly hardened on the grained surface before any attempt is made to coat the work with colour. The least tackiness in the varnish will arrest the progress of the operation, as the dark pigments used for the representation of walnut, etc., will inevitably make an ugly stain, removable only by the exercise of much care and patience. An interval of at least two or three days in dry summer weather, and of a week in the humid atmospheric conditions peculiar to winter, should be allowed between the varnishing of the grained panels and the addition of the decorations. If time permits a second coat of varnish, by all means let the work receive it before beginning the inlaying operations.

DISTEMPERING

35. Definition.—Distemper is composed of any colouring pigment mixed with water and size. In a sense, ordinary whitewash used for ceilings is a distemper. In distemper the colour is not dissolved, but is suspended in the vehicle, which is merely water, and its suspension is so uncertain that a slight addition of size is necessary to hold it in place upon the surface to which it is applied after the water has evaporated. The colours are all mixed just to the shade required, and no amount of dilution will render them softer or more delicate. Dilution simply depletes the effectiveness of the size, rendering the colour unstable and likely to drop from the surface in the form of powder.

36. Tools.—Distempering is executed with brushes made for the purpose, termed 10-ounce or 12-ounce brushes, comprising a long handle with two knots of long hair, and the ordinary sash tools described in *Painting and Decorating*, Part 1, with the addition of a few others of softer hair. When used to do distemper work, a broad flat brush is required to spread the colour rapidly over a considerable surface, as the colour dries quickly and is likely to show marks where the dried surface is overlapped by wet colour. It is, for this reason, desirable to mix a considerable quantity of distemper at one time, as it is almost impossible to secure the exact shade required to finish a surface started on with an insufficient quantity of colour ready mixed. The colour, as first laid, is several shades darker than when dry, and to ascertain the finished tint, it is customary to apply a small amount of the colour to some obscure part of the wall and let it dry before proceeding with the rest of the work. Then if the tint is not satisfactory, more pigment can be stirred into the solution until the desired colour is attained.

37. Limewashing.—To make limewash for ceilings and similar situations pure white lime should be obtained and mixed with water; the mixture is only used for work that is not really important. It is very cheap, and consequently can be often renewed. For better work, ceilings are whitened with a mixture made from whitening and water. **Whitening** is made by reducing

the best white chalk to a fine powder, and is sold by weight, generally in casks. **Size,** or very fine liquid glue, should be added to the whitening and water to make the whitening adhere to the surface after the water has evaporated.

To prepare whitewash, the whitening should be diluted in water to the consistency of a thick paste and about 1 pint of size should be added to every 3 or 4 pounds of whitening. The mixture should be well stirred until it becomes like a thick jelly, after which it should be allowed to stand for some time, when it can be diluted with water and used.

38. Clear-Cole.—On new plasterwork, before any whitewashing or distempering is done, a coat of **clear-cole** should be applied. This consists of size diluted with hot water and should be applied when hot ; it tends to fill up the pores of the plaster and prevents the distemper from soaking into the plaster and losing its colour.

39. Patent Distempers.—There are at present many special and patent distempers on the market. As one of the drawbacks to the use of ordinary distempers is that they so easily rub off the finished face, experiments have been made, so that now there can be procured what is known as a washable distemper, which does not come off a wall nearly to the same extent as an ordinary distemper. Other distempers have been introduced for use in damp situations.

GILDING

40. Tools.—The gilder's tools should be in the best of order.

Fig. 42

Fig. 43

His sable, or fitch, Fig. 42, his cutting knife, Fig. 43, and his

cushion, Fig. 44, should be scrupulously clean. When worn, the cushion should be re-covered with soft chamois leather. The gold leaf is spread on the cushion and cut into small squares or rectangles with the knife; a thin flat brush, called a **tip**, Fig. 45, is then used to lift the leaf from the cushion and place it upon the surface to be gilded. The tip should be first drawn across the hair or face in order to slightly moisten it, so that the leaf will adhere until transferred to the sized surface.

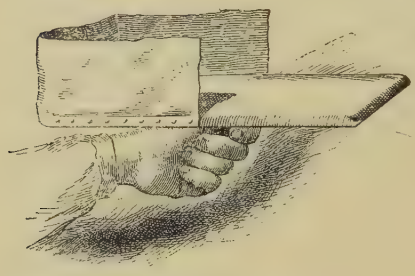


FIG. 44

41. Oil Gilding.—For interior work, **oil gilding** is the method most commonly selected on account of its wearing qualities. Finely ground yellow ochre is mixed with fat linseed oil; the older the oil the better. The drying is regulated by adding small quantities of copal varnish or Japan gold size, to be laid on with great regularity and well spread out with a sable or fitch.

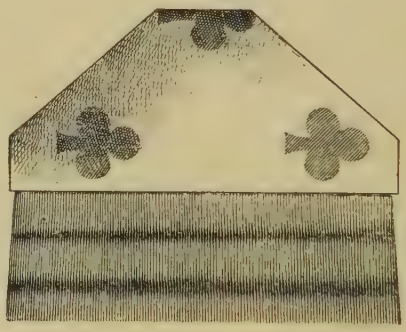


FIG. 45

42. Gold Size.—Gold size is first applied to the surface to be gilded and is allowed to partially dry, when it will be found to have a clean sticky surface. To this the gold leaf is applied from the cushion, or it may be obtained in the form of a book bound up alternately with leaves of specially prepared paper. One leaf at a time is taken from the book and applied to the gold-sized surface; when it is gently pressed on to the surface it will readily adhere.

Oil gold size being the best commodity, many gilders make their own, as being more reliable than any of the readily

purchasable kinds. It is simply a preparation of fat or linseed oil, thickened by age or exposure to the sun. For this purpose the oil which collects on the top of oil paint should, after standing a few weeks, be carefully poured into another vessel. Mixed with raw linseed oil, this is placed in a large, wide-mouthed pot, covered with a sheet of glass, to keep out dust particles. This is, in turn, put where it may, for 2 or 3 months, get the direct rays of the sun, during which time it must be occasionally stirred. If water is placed at the base of the pot, such impurities as may be in the oil will sink through the water to the bottom, greatly facilitating this stage of preparation. The oil, under this treatment, will, in the course of a few weeks, attain the consistency of syrup and may be poured off into bottles. This, again, should be heated gently until the oil once more becomes fluid, when it may be gently strained through coarse muslin to remove the sediment, after which it is stored in gallipots to protect it from the air. When required for use, a proportion of yellow ochre and chrome finely ground should be added to the oil, together with a small amount of best copal varnish, or gold size, after which the preparation will be ready for use. The usual time required for it to set properly on the surface is from 12 to 16 hours. Properly made, it will, after it has become set, hold the tack for 6 or 8 hours, or even longer.

Turpentine should never be added to oil gold size, as its evaporation greatly impairs the brilliancy of the gold, some work actually turning black in consequence of the use of turpentine as thinning. The best method is to thin out with oil or varnish. Oil gold size invariably tends, however, from its very nature, to produce a *ropy* surface, that is, a surface streaked with lines of uneven thickness or body. Hence, on broad surfaces, to ensure an even spreading of the vehicle, it must be carefully *laid on.*

43. Japan Gilding.—Besides oil gilding, there is the **Japan method of gilding,** and **water gilding,** used for frames, mirrors, and console tables. Ceiling work is usually executed in oil, but may be done, wholly or in part, in Japan gilding. Oil gilding is durable, rich, and brilliant, but Japan gilding is the

more expeditious, for, as the work is not liable to **bloom,** or become clouded and discoloured on the surface after drying, there is no necessity to size it after completion, as is the case with oil gilding. Japan, being the best vehicle for running the lines in a design, may also be preferred for such parts as do not present a solid or rounded surface. Japan gold size is, when used alone, too rapid a drier to ensure the requisite tack or adhesiveness ; most gilders, therefore, add a proportion of copal varnish. Japan size, if properly manipulated, should be ready for gilding in from 1 to 2 hours, and should, after being thus ready, hold the tack for at least an hour.

Oil size, from its liability to spread and form a ragged edge on the work, is not adapted to lining or to stencilling. Where the paint underneath is not properly hardened, the surface should, before gilding, be brushed over with white of egg and dusted with powdered whitening. This process, which arrests the adhesiveness of the paint, is unnecessary if the colours have been worked in flatting, provided the flatting itself has been properly made up.

In case the lines are to be run on a dark surface colour, or in juxtaposition thereto, the vehicle should be slightly stained by the addition of some finely ground chrome. Mouldings also may be gold sized with sable or fitch. Stencilling, too, may be done, and such parts as require pencilling in by hand readily completed.

44. Parchment Size. — To prevent blooming, the gilded surface should, on completion, be gone over with **parchment size,** which is made by melting parchment cuttings and diluting these with warm water. This is applied with a camel-hair brush passed lightly over the surface of the gilding. The greatest care must be taken to keep the apartment free from dust, both while the gold size is wet and tacky and while the parchment size is being applied or drying. Some gilders use common white size instead of parchment. Although considerably cheaper, it is, however, on account of inferior transparency, unfitted for good work. One coat of parchment size is sufficient for comparatively small surfaces, such as mouldings, etc. ; but

on a wider expanse of gilding, it is, in some instances, well to go over the surface even a third time, to make certain that the gold is fully covered, otherwise the work may, from the blooming of parts insufficiently sized, present a spotted appearance. The parchment cuttings for the size are heated gently

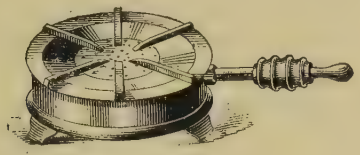


Fig. 46

Fig. 47

over a gas stove, as shown in Fig. 46, in an earthenware vessel, similar to that shown in Fig. 47, which is preferable to a metallic pot. Boiling water poured on a little isinglass makes a convenient size for gilding work.

45. Use of Gilding.—Generally speaking, it is impracticable to stencil ornamental patterns, especially those made up of minute parts, to be executed in oil size or paint. Oil size may be used as readily as Japan gold size in exterior work well above the level of the eye, but as oil size invariably spreads under the stencil plate, the Japan is, in many cases, preferable for stencilling in gold. In the case, for instance, of an ogee moulding, oil size must be altogether discarded, its greater bulk or consistency causing it to leave unsightly edges on the pattern, which not even careful cutting in afterwards with the ground colour can effectually obliterate. Japan gold size, being of a more fluid nature, will, if properly prepared by the addition of a slight modicum of good copal varnish, as the weather or temperature of the apartment may demand, yield work not necessarily requiring to be sized with a solution of parchment cuttings, as is the case with work rendered in the more solid vehicle of oil size.

46. In some cases it is essential to prepare painted work with white of egg and whitening, so that the gold may adhere only to the sized parts. A fruitful cause of the spreading of oil

size, and even Japan, is that decorators dust too great a quantity of whitening over the work. Some decorators rub a soft cloth over a ball of whitening and apply it with all the gritty particles to the work to be gilded. If an unpleasant aftertask of cutting in rough edges is to be avoided, tie the powdered whitening in a bag made of two or three folds of the finest muslin, removing any of the dust escaping from the meshes of the material. If the work is well covered with a solution of white of egg, the merest touch of the pounce bag should suffice. The white of egg prevents the gold leaf from adhering to the paint, and the whitening prevents the gold leaf from adhering to the white of egg. Thus it may, in a particularly hot room, happen that the white of egg may, if used with too small a proportion of water (an error to be carefully avoided), or from the extra tackiness of the ground work, prove difficult to remove, refusing, for instance, to yield easily to the persuasive influence of a soft damp sponge. If, in such a case, the gold leaf also adheres to the white of egg, the work becomes practically worthless.

The proportion of water should be rather more, and never less, than 4 ounces to the white of an egg. The work upon which the gilder is to exercise his skill being then very tacky, either from the humidity of the atmosphere or from too great a proportion of oil in the preparation of the colour, it is best to defer for a few days the commencement of operations. If the white of egg is too weak, the gold will stick to the work ; if too strong, the white of egg will remain where the gold is washed off, and the work will be found streaked in all directions with marks from every hair of the tool with which it was applied.

47. Without attempting to lay down any hard and fast standard of good taste in the use of gold leaf, it may be truly said that work otherwise good is as often marred by the abundance as by the poverty of the precious metal's display. Where it is sought to introduce gilding as an aid to decorative detail on the woodwork of an ordinary apartment devoted to living purposes, the wallpaper should be taken as much into account as the painting of the woodwork. Because the wallpaper happens to be of a certain tone, it does not follow that the painted

work must match it. Neither must it be supposed that a wall-paper, relying for effect upon metallic details in the design, needs the support of a quantity of gilding on the painting placed in juxtaposition with it. If, on the contrary, the walls have a mass of metal or gold, as the paper stainer generally terms it, introduced into their hangings, it is often better to dispense with gold in the woodwork, or to apply it so sparingly that the eye may find the repose so essential for appreciation and enjoyment. A mass of gilding on ceilings, walls, and woodwork, in an apartment illuminated by artificial light, often has an effect painful rather than pleasing, all being garish glitter rather than the calm and dignified harmony resulting from embellishment by a decorator of cultivated taste.

48. Where, for instance, the effect of an ornamented door panel would be spoilt if the mouldings round it were profusely decorated, the fillet next to the panel could be gilded, and the body or carved portion of the moulding painted in some harmonious tint. Waste of gold leaf is thus prevented, to say nothing of the greater facility with which oil size can be run upon the narrow flat by an expert pencil hand. If, on the other hand, the moulding of the door panel is exceptionally broad, and it is desirable to break the solidity of its appearance, cut on a stencil paper some simple ornament, such as a succession of triangular notches, the dog's tooth, or any running ornament of not too complex a character. Its execution in gold on the moulding, although the time taken is somewhat in excess of that needed to gild the whole member, will yield an artistic effect in the precise direction intended. No saving of gold will indeed be effected, for the gilder must, of necessity, cut his leaves into sections, each the actual width of the moulding. But the surplus gold leaf, removed in the usual manner, first by the dabber and finally with cotton wool, will add to the value and quantity of **skewings**, as the surplus gold leaf is called, and in some measure compensate for the additional labour. Haste, and the crowding together of two or three sets of workmen in the same place and time in which gilding is under execution, are conducive to wastefulness and

inefficiency. The skilled decorator will therefore make due provision to enable his gilders to pursue their work with the facilities ensured by freedom from interruption and such like inconveniences.

49. Decoration of a Door.—Fig. 48 shows a door that is to be finished in white and gold. When the paint is thoroughly hard,

FIG. 48

the parts to be gilded are judiciously selected. The transom light bears a heraldic design, which should be embossed on the glass. The members to be gilded are the fillet, bed mouldings,

and labyrinth or fret *a*, *b*, *c*, *d*; the key block or truss with the bed moulding and two bands forming side scrolls *e*, *f*, *g*; the fillet and bead of the architrave *h*, *i*, *j*; the raised ornament on the spandrel panels *k*, to be heightened on the edges only; the transom-bar cornice, fillets, and bed mouldings *l*, *m*, *n*; the abacus and volutes *o*, *p* on cap of pilasters; the stalks of the acanthus and the edges of the serrated leaf; the fillet or neck mouldings *q*; the bead moulding in the pilaster panel *r*; the base or torus moulding *s*; the door-joint strip with central and side strips *t*; the door panels *u*, *v*; the chamfer *w*. After gilding, a weak parchment or melted isinglass size is applied, care being taken not to run over on the surface of the white paint.

PAPER HANGING

50. Introduction.—The art of paper hanging is easily acquired, but the tasteful choice of paper for various situations is a gift of no such easy acquisition. The walls of a room should be regarded as the mere framework of what the room is to contain. Their decoration should therefore bring into prominence, rather than eclipse, the contents of the apartment. Wallpaper of glaring colour and gaudy ornamentation brings into the utmost conspicuousness that which should be an accessory only.

Wallpapering is an inexpensive way of making a decorative finish to the plaster on the walls in the interior of a building. The cost of paper is comparatively small, and an infinite variety of design and colours can be obtained suitable for all purposes, so that a new surface to the walls and ceiling of a room can be obtained easily whenever required.

51. Wallpaper.—English papers for hanging on walls are made to a standard width of 21 inches and are sold in rolls 12 yards long, each roll being termed a **piece**. Each roll therefore contains 7 yards super of paper, but there is a $\frac{1}{2}$-inch margin on each side which must be cut off before the paper is hung, thus reducing its width to 20 inches. French papers are smaller and vary considerably in size, but a usual standard for these is 9 yards long and 18 inches wide, or about 40 feet super to each

roll. Rolls of paper for dados and friezes are made in varying and special widths.

52. Kinds of Wallpapers.—It is not possible in a short space to describe all the methods by which wallpaper is made and finished. The methods adopted for applying the colour and finishing the surfaces are being constantly changed ; old methods are revived and used for a short time and new methods are being constantly introduced. The chief kinds of wallpapers, however, are the following :

Plain, or pulp, papers, in which the ground is formed by the paper itself, either white or tinted, as the case may be, and a pattern printed on it in one or more colours.

Flock papers, in which the pattern is printed on a tinted paper in a sticky composition of size and varnish, which is colourless. Flock, obtained from the surface of woollen cloth, is then dusted over the paper, and adhering only to the sticky parts forms the pattern.

Ingrain papers are ordinary or pulp papers into which a specially prepared fibre is incorporated, and are made by passing the papers through two machines, one of which prepares the pulp and the other adds the fibre or colour, which sinks into the pulp. Ingrain papers may be had either plain or self-coloured, that is, in one tint, or may be ornamented by means of printed patterns.

Sanitary papers are ordinary pulp papers treated with an oil medium during manufacture, to make the colours fast and enable the surface to be washed. The surface of a sanitary paper is generally shiny, but not always so. They are principally used for kitchens, bath rooms, water closets, etc.

Lining papers are coarse strong papers hung on walls and ceilings either where plaster is defective and uneven or to prevent the lime in new plaster from discolouring the wall paper. Special paper coated with pitch or with lead foil can be obtained, and is used for a similar purpose or where the wall is likely to be damp.

53. Other materials used for decorating walls and fixed by the paperhanger are :

Canvas, generally plain, but sometimes with a pattern dyed in various tints and chemically treated to prevent moisture from the paste showing through the surface.

Embossed papers, made principally from pulp, usually having only one tint, the pattern being formed by raising or embossing the surface of the material. There are many varieties of these, the best known being Anaglypta, Lincrusta, and Leatherette. Embossed papers are usually painted, after being hung, to a tint that will harmonize with the other decorations in the room in which they appear.

54. Hanging the Paper.—To prepare the walls for papering melt some size with hot water, taking care not to let it boil. Then give the walls a coat of a very weak solution of the same, with a broad flat brush, such as that shown in Fig. 49. To make a paste, put 2 pounds of fine flour in a pail, add cold water, and mix to a thin dough. Pound finely a piece of alum about the size of a small chestnut and mix it well into the paste. Then pour in about 6 quarts of boiling water, mixing with the paste while hot until the whole is brought to a proper consistency; use when cold. For Lincrusta, Anaglypta, and other heavy relief papers, add, when melted, a little thin glue, using the paste thick. The walls should be thoroughly dry before the paper is hung. The surface of walls, prepared for the first time, should be stopped, rubbed smooth with a piece of pumice stone or glasspaper, and then treated with a coat of size, which prevents the plaster from absorbing the paste.

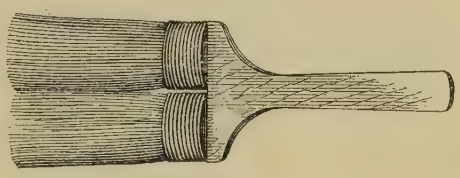


FIG. 49

55. In order to obtain a smooth surface, a plain, coarse, white lining paper is sometimes hung first. In hanging lining paper, the edges of adjacent pieces must not overlap, and, if found to do so, must be well rubbed down to prevent their showing through the wallpaper. In hanging all good papers, such as tinted ingrains, care must be taken to stop the action

of the plaster from destroying the colour by either tinting the size or using tinted or brown lining paper before hanging the chosen paper. Common papers are hung with the lap of their trimmed edges facing the light, so that they may cast

Fig. 50

no shadow. The finest papers are hung edge to edge, or butted together, and where the walls are damp, they should be covered first with pitch paper or prepared tin-foil. Canvas may be stretched tight over battens or furring strips, nailed to the plaster so as to leave an air space between the walls and the

paper, but this method has, however, disadvantages, as the canvas expands and contracts with changes in the weather. When canvas is resorted to, the heads of the nails securing the canvas should be covered with strips of common paper before the wallpaper is hung, but iron nails should be painted. In ceilings, the edges of the paper should run at right angles to the principal light of the room.

56. Trimming.—In papering a wall, the preparatives having been attended to, the paper is trimmed either with a pair of large scissors or by means of a trimming machine; plumb the wall, so as to hang the paper in perfectly vertical strips, as shown in Fig. 50. After hanging the paper, smooth it down with a smoothing brush, Fig. 51, to cause it to adhere to the wall surface throughout its entire length. Common papers need only be trimmed on one edge, better papers both edges. Heavy papers, such as Lincrusta, Anaglypta, or Japanese, must be trimmed by means of a long steel straightedge and sharp knife to cut true.

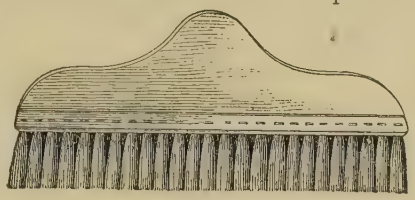


FIG. 51

57. Varnishing.—In cases where a varnished paper is required for certain walls, such, for instance, as those of a nursery, or bath room, or of narrow passages, or for the walls of more important rooms, the wall paper may be given two coats of sizing and then varnished in two coats or more. The second coat of sizing is applied to make sure that the surface of the wallpaper is entirely covered. A washable varnished paper is, however, manufactured and easily procurable. In preparing wallpaper to be varnished, use double or white size melted with boiling water, which should be applied while still warm. If, in applying the size, it is found that the colours in the paper rub up, the first coat of size must be sprayed on, or the remainder of the paper must be sent back to the makers to be dipped in size. The varnish used must be of a light nature, such as pale copal carriage or white spirit varnish.

58. Repapering.—In repapering walls, the old paper should be removed, the wall scraped, washed, stopped, and coated with size. If the old paper cannot be removed without injury to the wall surface, a coat of size should be applied to it and over that a coat of whitening and size, or distemper. A strong objection against the retention of old paper is that it is likely, through the decomposition of the paste securing it, to prove injurious to health.

ELECTRIC WIRING AND BELLS

(PART 1)

ELEMENTARY THEORY OF ELECTRIC CIRCUITS

INTRODUCTION

1. **Electricity** is the name given to the cause of all electric phenomena; though the exact nature of electricity is not known, many of its effects are well known, and methods for controlling and utilizing it are well understood. Electricity is neither a form of matter, as matter is generally understood, nor is it a form of energy, although energy is required to move it, and when in motion it is capable of doing work.

Electricity can manifest its presence in various ways. For example, it may cause attractions or repulsions of some kinds of matter; it may decompose into elements some kinds of matter through which it passes, as the decomposition of water into two gases, hydrogen and oxygen; it may cause a magnetic needle to deflect; it may cause physiological effects, or shocks, to the nervous system; or it may heat substances through which it passes.

2. Electricity may appear either to reside on the surface of bodies as a **charge,** or to flow through the substance or on the surface of a body as a **current.** That branch of the science which treats of charges on the surface of bodies is termed *electrostatics,* and the charges are said to be *static charges* of electricity.

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Electrodynamics is that branch of science which treats of the action of *electric currents.* Very little will be said in this Section about electrostatics, as an architect's work in connection with electricity will be almost wholly with electrodynamics.

DEFINITION OF ELECTRICAL TERMS

CONDUCTORS AND INSULATORS

3. Electricity cannot pass with the same freedom through all substances. Some, such as metals, allow it to pass at once to all parts; others, as glass and porcelain, prevent almost entirely any transmission of electricity. Metals, therefore, are said to be *good conductors* of electricity. Bodies have accordingly been divided into two classes: **non-conductors,** or **insulators,** those bodies that offer great resistance to the passage of electricity; and **conductors,** those that offer comparatively little resistance to its passage. This distinction is not absolute, for all bodies conduct electricity to some extent, while there is no known substance that does not offer some resistance to its flow.

RESISTANCE AND CONDUCTANCE

4. **Electric resistance** is a general property of matter, varying with different substances, by virtue of which matter *opposes,* or *resists,* the passage of electricity. Electric resistance may be compared to the friction of water against the sides of a pipe through which it is passing, or to the resistance of a substance to the passage of heat.

5. **Conductance,** or **conductivity,** is the facility with which a body transmits electricity, and is the reciprocal, or opposite, of resistance. For instance, copper is of low resistance and high conductance; wood is of high resistance and low conductance.

Table I gives a list of a few conducting and non-conducting substances arranged in the order of their conductance, beginning with silver, which is the best conductor known. The division is made only as a guide. There are many other

TABLE I

CONDUCTORS AND INSULATORS IN THEIR ORDER OF VALUE

Conductors	Insulators (Non-Conductors)	
Silver	Dry air	Glass
Copper	Shellac	Mica
Other metals	Paraffin	Ebonite
Charcoal	Amber	India-rubber
Plumbago	Resin	Silk
Moist earth	Sulphur	Paper
Water	Porcelain	Oils

substances that might be included among either the conductors or the insulators. A general idea of these values may be obtained from the fact that water has about 6,754 million times greater resistance than copper.

ELECTRIC CURRENT

6. It must be understood that electricity is a condition of matter and not matter itself, for it possesses neither weight nor extension. Consequently, the statement that electricity is *flowing* through a conductor must not be taken too literally; it must not be supposed that any material substance, such as a liquid, is actually passing through the conductor in the same sense as water flows through a pipe. The statement that electricity is flowing, or that a *current* of electricity is passing, through a conductor is only another way of expressing the fact that the conductor and the space surrounding it are in different conditions than usual, and that they for the time being possess unusual properties. The action of an electric

current, however, is quite similar in many respects to the flow of liquids, and the study of electric currents is much simplified by the analogy.

7. There are two kinds of electric current ; namely, **direct, or continuous, current,** which always flows in the same direction, and **alternating current,** which regularly reverses its direction of flow a definite number of times per second. As the theory of alternating currents is somewhat complicated, and the additional precautions necessary in wiring for alternating currents are more easily explained in the practical portion of this Section, this part will deal entirely with the theory of direct currents.

POTENTIAL AND ELECTROMOTIVE FORCE

8. In order to cause electricity to move, there must be created an electric pressure, just the same as to cause water to move, there must be a water pressure. The study of *Electrodynamics* naturally includes that of the creation of electric pressures and the movements of electricity.

9. **Electric Potential.**—The term **electric potential** used with reference to electricity is analogous to *pressure* in gases, *head* in liquids, and *temperature* in heat. In hydraulics, the pressure required is often produced by the fall of water from a high level to a lower one. The pressure produced is directly proportioned to the height from which the water falls, that is, to the difference of level. This difference of level is known as the *head* of water.

In electrodynamics the *head* required to set electricity in motion is represented by **potential** or **electromotive force.** For convenience, it has been arbitrarily assumed and universally adopted that that electric condition called *positive* is at a *higher potential* than that called *negative*, and that an electric charge, or current, flows *from* a positively *to* a negatively electrified body. It is customary to indicate a part which is electrically positive by a + sign, and one that is negative by a — sign.

10. The zero or normal level of water is taken as that of the surface of the sea, and the normal pressure of air as that of the atmosphere at the sea level; similarly, the earth may be regarded as a reservoir of electricity of infinite quantity, and its potential may be taken as zero. All electric charges, or currents, have the tendency to reach this zero level, exactly as water on a mountain top tends to flow to the sea level; hence, it becomes necessary to insulate most electrical apparatus, otherwise the electric charge, or current, will leak away to the earth. The electric condition that is called positive is assumed to be at a higher potential than the earth, and that called negative is assumed to be at a lower potential than that of the earth.

11. Electromotive Force.—The term **electromotive force,** usually written E.M.F., or E., is employed to denote that which moves or tends to move electricity from one place to another. A *difference of electric potential* (sometimes written P.D.) between two points is, as the expression implies, the difference between the electrical pressure at one point and the electrical pressure at the other. It is a measure of the pressure required to send a given current through a conductor between the points at which the difference of pressure exists.

12. The Volt.—In order to express the value of quantities, there must be units. For example, the length of a wall is expressed in units called feet. The pressure of water on the sides of a pipe conducting water subjected to pressure is expressed in units called pounds; the temperature of a body is expressed in units called degrees; likewise, electric pressure, difference of potential, or electromotive force, as it is variously called, is expressed by means of a unit called the **volt.** Thus, an electromotive force of a number of volts is spoken of in a manner somewhat analogous to the expression of a water pressure of a number of pounds. There does not need to be a movement of electricity in order to have an electromotive force any more than there needs to be a current of water through the pipe in order to have a water pressure. The volt is the practical unit of electromotive force.

METHODS OF PRODUCING ELECTROMOTIVE FORCE

13. An electromotive force may be produced, or generated, in a number of different ways, among which are the following :

1. By friction and electrostatic induction.

2. By dipping the ends of two strips of dissimilar materials into a liquid that has a greater tendency to chemically act on one material than on the other. The electromotive force is due to chemical action, or affinity, between the strips and the liquid.

3. By moving a conductor across a magnetic field.

Of these, the second and third are the methods of practical importance. The second method is used in electric-bell and telephone work, while the third involves the principle of the dynamo, a type of electric machine used for the production of the electromotive force for practically all electric lighting and power ; but as it comes within the province of the engineer, rather than that of the architect, it will not be further described here.

14. The Primary Cell.—If two dissimilar materials, as zinc and copper or zinc and carbon, are partially or wholly immersed in saline or acidulated water and are brought in electric contact outside the liquid, chemical action will occur between the two materials and the liquid, a difference of potential is produced, and an electric current will flow through the liquid and the contact in the direction shown by the arrows, Fig. 1, in which is shown an arrangement, known as a **primary cell.** A vessel A contains the liquid, which may be a dilute solution of sulphuric acid, a copper plate C and a zinc plate Z are partially immersed in the liquid and are connected outside by twisting their wire terminals together. The arrows show the direction of the current flow. The liquid is called the **electrolyte,** and it must be such that it will act chemically more readily on one of the two materials than on the other, in order to produce any difference in potential or electromotive force between the two.

The two dissimilar materials, when spoken of separately, are called **elements,** or **plates.** In any primary cell, the element, or plate, on which the chemical action is the more vigorous

is known as the *positive plate*, and the binding post, or terminal, attached to it is known as the *negative pole*. The other plate is the *negative plate* and its terminal is the *positive pole*. The positive pole is indicated by a plus (+) sign, and the negative pole by a minus (—) sign, respectively. In Fig. 1, the copper plate *C* is the negative plate and the zinc plate *Z* the positive plate. The poles are also called *terminals*.

15. Chemical Action in a Primary Cell.—When a strip of zinc is immersed in dilute sulphuric acid, bubbles of a gas, called hydrogen, are formed and the zinc begins to dissolve. The relation between the sulphuric acid and the zinc is similar to that of a piece of burning wood and the oxygen of the air. In both cases a union is eagerly sought and heat is produced. When a copper plate is also inserted in the solution and joined to the zinc by a wire, as in Fig. 1, heat is not at once evident. A difference of potential is first produced, presumably at the contact surface between the zinc and the acid, by reason of which an electric current is sent through the cell and the wire. Eventually the wire becomes heated by the current; the chemical combination of the substances in the cell is therefore also in this case productive of heat.

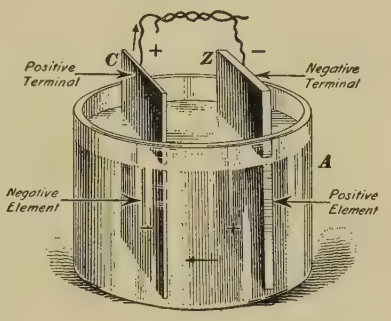

FIG. 1

When the zinc dissolves, the released chemical elements combine with the electrolyte and form other substances. In the elementary cell, Fig. 1, *zinc sulphate* is formed, and the hydrogen gas is collected at the copper plate, which soon becomes covered with clearly visible bubbles of gas. The zinc sulphate immediately dissolves, and so makes no change in the appearance of the liquid.

In a simple cell, as shown in Fig. 1, these bubbles on the positive plate soon become very thick, while the flow of current is greatly decreased. A cell in such a condition is said to be

polarized. Both the decomposition of the electrolyte and the polarization of the cell decrease the electromotive force. If a substance with which the free hydrogen can unite is placed near the positive plate, the accumulation of gas bubbles on it will be prevented and the electromotive force of the cell will be increased. Such a substance is known as a **depolarizer.**

16. Battery.—When a number of cells are joined together, according to certain principles, they constitute a **battery.** The poles of a cell are used to connect it to any exterior conductor or to another cell. In electric diagrams, cells are represented as drawn in Fig. 2, the long thin line representing the positive, and the short thick one the negative, plate. In this illustration M and N each represent a single cell; the two cells joined together in this manner constitute a battery, a and d representing the terminals of the battery, as well as the positive pole of M and the negative pole of N, respectively. The negative pole of M and the positive pole of N are b and c, respectively. The combination of the battery and the conductor constitutes a *circuit*, the arrows indicating the direction in which the current flows round the circuit. Other varieties of a circuit will be described in succeeding articles. If there is only one cell in a circuit, it may be called a battery; in fact, a single cell is often called a battery.

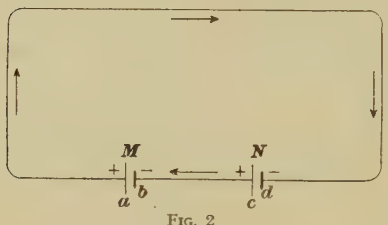

FIG. 2

UNITS OF CURRENT, AND RESISTANCE

17. The Ampere.—The practical unit of electric current is the **ampere.** If an electric current is made to pass through water, the water will be broken up, or decomposed, into two gases, hydrogen and oxygen. The rate of decomposition is directly proportional to the strength of the current and the time. For example, 2 amperes in 1 second will decompose twice as much water as 1 ampere in 1 second, and 2 amperes in 2 seconds

will decompose as much as 4 amperes in 1 second, etc. It has been experimentally determined and universally accepted that 1 ampere is that strength of current which will decompose ·00009324 gramme of water in 1 second.

18. The Ohm.—It is explained in Art. 4 that a current of electricity has to overcome a certain amount of resistance, which varies according to the nature of the substance through which it passes. Electric resistance enters so much into calculations for electric wiring that a unit is necessary to express its value. The unit of electrical resistance, now universally adopted, is called the **international ohm.** One international ohm is the resistance offered by a column of pure mercury 106·3 centimetres in length and 1 square millimetre in sectional area at 32° F. The dimensions of the column expressed in inches are as follows: length, 41·85 inches; sectional area, ·00155 square inch. The word international will be omitted and simply the word ohm used.

For convenience in stating very small resistances, a smaller unit, equal to one millionth ($\frac{1}{1000000}$) part of an ohm, is used and is called a **microhm.** For high resistances the unit taken is equal to one million (1,000,000) ohms and is called a **megohm.**

RELATIONS BETWEEN RESISTANCE AND THE DIMENSIONS OF A CONDUCTOR

19. The flow of water through a pipe is decreased if the length of the pipe is increased or if its diameter is decreased. This is because in either case the amount of friction between the walls of the pipe and the water is increased. Similarly, in an electric circuit the resistance offered by any conductor is directly proportional to its length and inversely proportional to its cross-sectional area.

20. Specific Resistance.—If a number of conductors are made of the same length and the same sectional area, the resistances need not necessarily be alike unless all the conductors are made of the same material. The influence of the nature of the substance itself on its resistance can therefore easily be determined by testing the resistances of various substances formed into

conductors of uniform lengths and sectional areas. The resistance ascertained in this manner is called the **specific resistance** of the substance.

In what follows, the specific resistance is that resistance possessed by a piece of the substance 1 inch long and 1 square inch in sectional area at 32° F. It may also be expressed as the resistance between two opposite faces of a cube of that substance. It is obvious, therefore, that the resistance of any conductor is directly proportional to the specific resistance of the material of which it is composed.

21. By combining the relations between the dimensions of a conductor at its specific resistance, as stated in Arts. **19** and **20,** the following rule is obtained :

Rule.—*The resistance, in ohms, of any conductor is equal to the product of its specific resistance, in ohms per cubic inch, and its length, in inches, divided by its cross-sectional area, in square inches.*

Or, if R = the resistance in ohms,
l = the length of the conductor in inches,
s = the cross-sectional area in square inches,
and p = the specific resistance in ohms per cubic inch,

then,
$$R = \frac{p\,l}{s}$$

Example.—The cross-sectional area of a No. 8 S.W.G. wire is ·02 square inch, and the specific resistance of copper ·634 microhm per cubic inch. Calculate the resistance of 110 yards of the wire.

Solution.—It is first necessary to reduce yards to inches, $110 \times 36 = 3{,}960$; and microhms to ohms, $·634 \div 1{,}000{,}000 = ·000000634$. Substituting in the formula,

$$R = \frac{·000000634 \times 3960}{·02} = ·126 \text{ ohm, nearly.} \quad \text{Ans.}$$

OHM'S LAW

22. In every electric circuit in which direct current is flowing, there are, particularly, three factors, the true relation of which should be clearly understood. These three factors are :

1. The force tending to move the electricity, termed *electromotive force* (written E.M.F., or E), of which the practical unit is the *volt.*

2. The rate of flow of the electricity, termed *current* (written C), of which the practical unit is the *ampere.*

3. The opposition to the flow of electricity, termed *resistance* (written R), of which the practical unit is the *ohm.*

23. In general, it may be stated that a result is equal to the effort put forth divided by the opposition, or,

$$\text{result} = \frac{\text{effort}}{\text{opposition}}$$

For example, the rate of flow of water through a pipe depends directly on the pressure applied to the water and inversely on the resistance offered by the pipe to the passage of water. The rate of flow may be increased either by increasing the pressure, or by enlarging the pipe, or by making the interior of the pipe smoother and thus decreasing its resistance.

24. A German electrician, Dr. G. S. Ohm, was the first to discover that the general law just stated applies to electric circuits ; hence, the ratio

$$\text{strength of current} = \frac{\text{electromotive force}}{\text{resistance}}$$

is known as **Ohm's law.**

Ohm's Law.—*The strength of a continuous current of electricity in a circuit is directly proportional to the electromotive force, and inversely proportional to the resistance of the circuit, and is equal to the quotient arising from dividing the electromotive force by the resistance.*

25. The law may be stated in practical units by the following rules and formulæ :

Rule I.—*The strength, in amperes, of a continuous current* (*C*) *flowing in a closed circuit, when the electromotive force* (*E*) *and the total resistance* (*R*) *are known, is found by dividing the electromotive force, in volts, by the total resistance, in ohms ;* that is,

$$\text{current in amperes} = \frac{\text{electromotive force in volts}}{\text{resistance in ohms}}$$

or,

$$C = \frac{E}{R} \qquad (1)$$

Rule II.—*The total resistance* (R), *in ohms, of a closed circuit, when the electromotive force* (E) *and the continuous current* (C) *are known, is found by dividing the electromotive force, in volts, by the current, in amperes ;* that is,

$$\text{resistance in ohms} = \frac{\text{electromotive force in volts}}{\text{current in amperes}}$$

or,
$$R = \frac{E}{C} \qquad (2)$$

Rule III.—*The total electromotive force* (E), *in volts, developed in a closed circuit, when the continuous current* (C) *and the total resistance* (R) *are known, is found by multiplying the current, in amperes, by the total resistance in ohms ;* that is,

$$\text{electromotive force in volts} = \text{current in amperes} \times \text{resistance in ohms}$$

or,
$$E = C \times R \qquad (3)$$

26. The following examples show the application of Ohm's law. Formula **1**, Art. **25**, determines the strength of current that will flow in a conductor of a given resistance, when the pressure in volts is known.

Example 1.—A circuit has a resistance of 50 ohms and an available pressure of 100 volts ; what is the strength of the current in amperes ?

Solution.—Applying formula **1**, Art. **25**,

$$C = 100 \div 50 = 2 \text{ amperes.} \quad \text{Ans.}$$

Example 2.—If the pressure in a circuit is 3 volts and the resistance is 15 ohms, how many amperes will flow ?

Solution.—Applying formula **1**, Art. **25**,

$$C = 3 \div 15 = \tfrac{1}{5} \text{ ampere.} \quad \text{Ans.}$$

Example 3.—What current can be made to flow through a circuit having a resistance of 10 ohms, if an electromotive force of 100 volts is applied ?

Solution.— $E = 100$; $R = 10$; hence, by formula **1**, Art. **25**, the required current

$$C = 100 \div 10 = 10 \text{ amperes.} \quad \text{Ans.}$$

27. In case the electromotive force, or difference of potential, E is known, formula **2**, Art. **25**, must be used to calculate the resistance of the circuit that will allow a given current C to flow through it.

EXAMPLE 1.—The electromotive force of a circuit is 500 volts; it is desired to have a current of ·5 ampere flowing in it; what should be the resistance of the circuit?

SOLUTION.—According to formula **2**, Art. **25**,

$$R = 500 \div \cdot 5 = 1{,}000 \text{ ohms.} \quad \text{Ans.}$$

EXAMPLE 2.—Through what resistance can a current of 50 amperes flow, if the electromotive force is 500 volts?

SOLUTION.— $C = 50$; $E = 500$; hence, by formula **2**, Art. **25**, the required resistance

$$R = 500 \div 50 = 10 \text{ ohms.} \quad \text{Ans.}$$

28. To find how much pressure will be required to force a given current through a given resistance, it will be necessary to use formula **3**, Art. **25**.

EXAMPLE 1.—How much pressure will it take to force a current of 18 amperes through a resistance of 5 ohms?

SOLUTION.—Applying formula **3**, Art. **25**,

$$E = 18 \times 5 = 90 \text{ volts.} \quad \text{Ans.}$$

EXAMPLE 2.—What voltage is required to send a current of 25 amperes through a resistance of 4 ohms?

SOLUTION.— $C = 25$; $R = 4$; hence, by formula **3**, Art. **25**, the required voltage

$$E = 25 \times 4 = 100 \text{ volts.} \quad \text{Ans.}$$

EXAMPLES FOR PRACTICE

29. 1. The total resistance of a circuit is 49·3 ohms; if the current is 2·73 amperes, what is the total electromotive force, in volts?

Ans. 134·589 volts

2. A difference of potential of 110 volts exists between the terminals of a conductor whose resistance is 20 ohms; find the current flowing through the conductor. Ans. 5·5 amperes

3. A circuit has an available pressure of 220 volts; what is its resistance if a current of 50 amperes can flow through it? Ans. 4·4 ohms

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DROP OF POTENTIAL

30. In any electrical circuit a certain amount of pressure is lost in overcoming the resistance of the conductors. This lost pressure is known as **drop of potential, voltage drop,** or simply **drop.**

When water is flowing through a pipe it suffers a loss in pressure. At one end of the pipe the pressure may be 50 pounds per square inch, but, if the pipe is long enough, the pressure may be reduced so much by frictional resistance and other causes, that at the other end of the pipe the water may flow at a pressure of not more than 1 pound per square inch. If pressure gauges were inserted at various points along the pipe, this gradual loss in pressure could easily be observed.

A similar loss of pressure is also found in an electric circuit. For instance, if measurements by suitable instruments show that while a current is passing through the conductor *a d*, Fig. 3, the pressure at *a* is 4 volts and at *b* 3 volts, it proves that in order to force the electric current from point *a* to *b* a pressure of $4 - 3 = 1$ volt is required. If the current strength is known, and also the resistance in ohms of any particular part of a circuit, the loss in pressure, or of potential, may be found by means of Ohm's law.

31. The electromotive force in the part *a b*, Fig. 3, that is, the force active in sending the current from *a* to *b*, is evidently equal to the difference of potential between these two points. In formula **3**, Art. **25**, this difference of potential, or E.M.F., is indicated by the letter E, and $E = CR$.

EXAMPLE.—Fig. 3 represents part of a circuit in which a current of 2·5 amperes is flowing. The resistance from *a* to *b* is 10 ohms; from *b* to *c*, 15 ohms; and from *c* to *d*, 20 ohms. Find the difference of potential between *a* and *b*, *b* and *c*, *c* and *d*, and *a* and *d*.

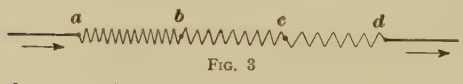

FIG. 3

SOLUTION.—Since, by Ohm's law, $E = C R$, the difference of potential between

$$a \text{ and } b \text{ is } 2{\cdot}5 \times 10 = 25 \text{ volts}$$
$$b \text{ and } c \text{ is } 2{\cdot}5 \times 15 = 37{\cdot}5 \text{ volts}$$
$$c \text{ and } d \text{ is } 2{\cdot}5 \times 20 = 50 \text{ volts}$$
$$a \text{ and } d \text{ is } 25 + 37{\cdot}5 + 50 = 112{\cdot}5 \text{ volts}$$

or, the drop in potential between *a* and *d* is 112·5 volts. Ans.

32. In a great many cases it is desirable to have the current flow from the source a long distance to some electric device, such as an incandescent lamp or an electric motor, and return without causing an excessive drop of potential in the conductors

leading to and from the two places. In such circuits, the greater part of the total generated electromotive force is expended in the device itself, and only a small fraction of it is lost in the rest of the circuit. Under these conditions, it is customary to decide on a certain drop of potential beforehand, and from that and the current calculate the resistance of the two conductors.

EXAMPLE.—It is desired to transmit a current of 10 amperes to an electric device situated 1,000 feet from the source; the total generated electromotive force is 110 volts, and only 5 per cent. of this is to be lost in the conductors leading to and from the two points. Find (*a*) the total resistance of the two conductors, and (*b*) the resistance per foot of the conductors, assuming each to be 1,000 feet long, and that the resistance of 1,000 feet is 1,000 times the resistance of 1 foot.

SOLUTION.—(*a*) 5 per cent. of 110 volts is $110 \times \cdot 05 = 5 \cdot 5$ volts, which represents the total drop of potential in the two conductors. Then, $E = 5 \cdot 5$ volts, $C = 10$ amperes, and $R =$ the total resistance of the two conductors, and, by Ohm's law,

$$R = 5 \cdot 5 \div 10 = \cdot 55 \text{ ohm.} \quad \text{Ans.}$$

(*b*) The resistance of the conductor is directly proportional to its length, and hence the resistance of 1 ft. is $\frac{1}{2000}$ of the resistance of 2,000 ft. But the resistance of 2,000 ft. is ·55 ohm; hence, the resistance per foot is

$$\cdot 55 \div 2{,}000 = \cdot 000275 \text{ ohm.} \quad \text{Ans.}$$

EXAMPLES FOR PRACTICE

33. 1. In a part of a closed circuit, the drop of potential caused by the resistance of the conductor is 10 volts; if the current flowing is 4 amperes, what is the resistance of that part of the circuit?

Ans. 2·5 ohms

2. The total generated electromotive force in a circuit is 220 volts. A current of 10 amperes is transmitted to and from a device situated some distance from the source, with a drop of potential of 10 per cent. Find the total resistance of the two conductors leading to and from the device.

Ans. 2·2 ohms

ELECTRIC POWER

34. Work and Power.—The terms *work* and *power* are often supposed to mean the same thing, but they are distinctly different. In order to understand this difference, let it be supposed that a tank placed 20 feet above the ground is to

be filled with water from a well. The water is to be forced into the tank through a pipe by means of a hand pump. To fill the tank requires a certain amount of work at the pump. This amount will be the same whether a man does it in 4 hours or more slowly in 6 hours. In a general sense, **work** means simply the overcoming of resistance. Some of the resistance to be overcome in this instance is the friction of the pump parts and the resistance which the water meets in flowing through the pump and the pipes; but the main resistance is that offered by gravity, that is, the lifting of the water to a higher level.

If one man can pump the water into the tank more quickly than another man, it means that he is more *powerful*. The work performed is the same in either case. **Power** refers to the *rate* at which work is done. The more quickly the work is performed, the greater is the power available. Work need not necessarily consist in lifting weights; it may, for instance, be productive of heat. If a grindstone is turned for the purpose of polishing the surface of a casting, the work at the crank is transformed to a great extent into heat.

35. Work, or energy, is required to force a current through a conductor; this energy is expended in heating the conductor. If the current is strong enough, the conductor will be melted or burnt out. Similarly, if a stream of water is forced through a pipe, some heat will be developed, due to the friction of the water against the interior of the pipe. The heat will, of course, be dissipated before the pipe heats sensibly, but accurate measurements will show a slight rise in the temperature of the water and the pipe. If the pipe opposed no resistance to the passage of the water, there would be no friction and consequently no heat development. Likewise, if an electric conductor did not resist the flow of electricity, it would not be heated.

If a certain quantity of electricity, when flowing round a circuit, produces a certain amount of heat, work is performed. Whether this increase in temperature is produced in 5 seconds or 5 minutes does not affect the quantity of work performed.

In this Section no reference is made to the unit quantity of electricity, called *coulomb*, but simply to the *rate* at which this quantity is sent round a circuit. The term *ampere* means that one unit quantity of electricity is passing any one point in a circuit in one second. It refers, therefore, to rate of flow, and the amount of work performed must increase with the strength of the current.

36. The terms work and energy are not really synonymous terms. **Energy** may be said to be work stored up, ready for use when an opportunity offers itself. For instance, to raise the weight of a clock requires work. The weight in its highest position represents work stored up, or energy. When the weight drives the clock, it performs work and is gradually descending while doing so. The zinc and electrolyte in a primary cell represent energy; while the zinc is dissolving, energy is spent and work is performed in sending an electric current through the circuit connected with the cell.

37. The Watt.—The **watt** is the unit of electrical power and is the rate at which work is performed when a current of 1 ampere is forced through a circuit having such a resistance that a pressure of 1 volt is required. From this definition the following rule is deduced:

Rule.—*In an electric circuit through which a direct current is flowing, the power* (W) *in watts, is equal to the current* (C), *in amperes, multiplied by the electromotive force* (E), *in volts;* or,

$$W = E\,C \qquad (1)$$

This formula may also be used in the following forms:

$$E = \frac{W}{C} \qquad (2)$$

and

$$C = \frac{W}{E} \qquad (3)$$

EXAMPLE 1.—If the electromotive force at the terminals of an electric device is 220 volts and the device takes a current of 5 amperes, how many watts are consumed?

SOLUTION.—By the formula just stated,

$$W = 5 \times 220 = 1{,}100 \text{ watts.} \quad \text{Ans.}$$

EXAMPLE 2.—How many watts are consumed by a 32-candlepower, 110-volt lamp, if it takes 1·2 amperes current?

SOLUTION.—By the formula just given,

$$W = 1{\cdot}2 \times 110 = 132 \text{ watts.} \quad \text{Ans.}$$

38. Power Absorbed in a Circuit.—It has been shown in Art. **30** that in every circuit, pressure is lost in overcoming the resistance of the conductors, and that the value of these lost volts may be determined by the formula

$$E = C\,R$$

By Art. **37** the power $W = E\,C$. Substituting in this equation the value of E, the formula becomes

$$W = (C\,R)\,C = C^2R$$

from which may be deduced the following rule:

Rule.—*The power, in watts, absorbed in any circuit is equal to the square of the current, in amperes, multiplied by the resistance, in ohms.*

The power lost in the conducting wires is wasted in heating them, and the application of the above formula is important, as it will be seen that a heavy current forced through wires of high resistance might lead to dangerous heating, and even fire.

EXAMPLE 1.—How much power is expended in a circuit whose resistance is 2·5 ohms when a current of 5 amperes is flowing?

SOLUTION.—By substitution in the formula $W = C^2\,R$,

$$W = 5 \times 5 \times 2{\cdot}5 = 62{\cdot}5 \text{ watts.} \quad \text{Ans.}$$

EXAMPLE 2.—If the resistance of a 16-candlepower, 110-volt incandescent lamp is 220 ohms: (*a*) how much current does such a lamp take? (*b*) how much power is expended in it?

SOLUTION.—(*a*) By Ohm's law,

$$C = 110 \div 220 = {\cdot}5 \text{ ampere.} \quad \text{Ans.}$$

(*b*) By the formula,

$$W = {\cdot}5 \times {\cdot}5 \times 220 = 55 \text{ watts.} \quad \text{Ans.}$$

39. The Kilowatt.—The watt is too small to express conveniently the large values of electric power frequently used; hence, the **kilowatt**, equivalent in value to 1,000 watts, is a convenient unit much in use. Kilowatt, or kilowatts, is very frequently written K.W. For use in the foregoing formulæ it is necessary to reduce kilowatts to watts. For example, if it is

desired to ascertain the voltage of a current of 50 amperes, when 10 kilowatts are spent in the circuit, apply formula 2, Art. 37 :

$$E = \frac{W}{C} = \frac{10 \times 1{,}000}{50} = 200 \text{ volts ; and not } \frac{10}{50} = \cdot 2 \text{ volt.}$$

EXAMPLES FOR PRACTICE

40. 1. Given an electromotive force of 80 volts and a resistance of 2 ohms, find the power in watts and kilowatts.

Ans. 3,200 watts, or 3·2 K.W.

2. Given a resistance of 11·8 ohms and a strength of current of 20 amperes, find the power, in watts and kilowatts.

Ans. 4,720 watts, or 4·72 K.W.

3. Given an electromotive force of 112 volts and a strength of current of 12 amperes, find the power in watts and kilowatts.

Ans. 1,344 watts, or 1·344 K.W.

41. Electric Horsepower.—The unit of mechanical power is the *horsepower*. One horsepower equals the work done when a weight of 550 pounds is lifted vertically 1 foot in 1 second, or when a weight of 33,000 pounds is lifted vertically 1 foot in 1 minute ; that is, one mechanical horsepower is the equivalent of 550 foot-pounds per second, or 33,000 foot-pounds per minute. One mechanical horsepower expressed in electric units equals 746 watts ; hence, 746 watts is termed an **electric horsepower.**

EXAMPLE.—How many electric horsepower is consumed by a device that takes 68 amperes at 220 volts ?

SOLUTION.—The watts consumed are $68 \times 220 = 14{,}960$. One electric horsepower is 746 watts ; therefore,

$14{,}960 \div 746 = 20$ H.P., about. Ans.

The unit of electrical energy or **Board of Trade unit** *is that energy expended in applying the kilowatt for one hour,* known also as the **kilowatt-hour.** The kilowatt-hours used in a circuit are, then, equivalent to the product of the kilowatts and the hours. For example, if the electric lamps in a shop require 1·5 kilowatts and the lamps are kept lighted 5 hours a day, there will be consumed each day $1{\cdot}5 \times 5 = 7{\cdot}5$ kilowatt-hours. Board of Trade unit is abbreviated B.T.U.

42. A smaller unit, the **watt-hour,** is the work done when 1 watt has been expended for 1 hour. This is seldom used for practical measurements of energy.

EXAMPLE.—A large hall is lighted by fifty 32-candlepower, 110-volt incandescent lamps, each lamp requiring 1 ampere. If the average drop is 3 per cent. of the pressure at the lamps, find : (*a*) how much power in kilowatts is expended in the wires ; (*b*) how many watts are used in the lamps ; (*c*) how much energy in Board of Trade units is wasted in the wires in 5 hours ; (*d*) how much energy is used in the lamps in 5 hours.

SOLUTION.—(*a*) The lamps require a total current C of 50 amperes. The small letter e is here used to distinguish between the total voltage E and the drop in any given part of the circuit. It is used in the formulæ the same as E. The drop e in the wires is 3 per cent. of 110, or

$$e = \frac{3 \times 110}{100} = 3{\cdot}3 \text{ volts}$$

Applying formula **1,** Art. **37,**

$W = 3{\cdot}3 \times 50 = 165$ watts, $165 \div 1{,}000 = {\cdot}165$ K.W. Ans.

(*b*) The lamps consume 50 amperes at 110 volts, and by formula **1,** Art. **37,**

$W = 110 \times 50 = 5{,}500$ watts. Ans.

(*c*) The power lost in the wires is 165 watts, or ·165 K.W., and in 5 hr. the energy loss is

$5 \times {\cdot}165 = {\cdot}825$ B.T.U. Ans.

(*d*) The power used in the lamps is 5,500 watts, or 5·5 K.W. and in 5 hr. the energy consumption is

$5 \times 5{\cdot}5 = 27{\cdot}5$ B.T.U. Ans.

ELECTRICAL CIRCUITS AND CONNECTIONS

DEFINITIONS OF TERMS USED

43. An **electric circuit** is a path composed of a conductor, or of several conductors joined together, through which an electric current may flow from a given point round the conducting path back again to its starting point.

A circuit is **broken,** or **opened,** when its conducting elements are disconnected in such a manner as to prevent the current from flowing.

A circuit is **closed,** or **completed,** when its conducting elements are so connected as to allow the current to pass.

A circuit in which the conductors have come in contact with the earth, or with some electric conductor leading to the earth, is said to be an **earthed circuit,** and the contact is called an **earth.**

A path of low resistance across the terminals of a voltaic cell or of a dynamo or of any source of electromotive force is

called a **short circuit**; for example, in Fig. 1, the cell is short-circuited by the contact of its wire terminals. Two earths, one on each terminal of a cell or of a dynamo, may produce a short circuit.

The **external circuit** is that part of a circuit which is outside, or external, to the source of electricity.

The **internal circuit** is that part of a circuit which is included within the source of electricity.

In the case of the simple cell, as shown in Fig. 1, the internal circuit consists of the two metallic plates, or elements, and the liquid, or electrolyte; the external circuit is the wire connecting the plates together outside the electrolyte.

44. Arrangement of Circuits.—A circuit is usually made up of at least three parts: (1) The battery, dynamo, or other source of electrical energy; (2) the apparatus which transforms this energy into the form in which it is practically applied: the lamp for light, the motor for power, or the radiator for heat; and (3) the connecting wires.

Electrical apparatus is connected on one of three systems, which will be described in detail later, in *series*, in *parallel*, or in a combination of the two known as *series-parallel* or *multiple-series*.

SERIES CIRCUITS

45. Current and Resistances in Series Circuits.—*Conductors are said to be connected in series when they are so arranged that the whole of the current flows successively through each of them.*

Fig. 4 represents a series circuit in which the current may be imagined to flow successively, by means of the connecting wires *a*, *b*, *c*, and *d*, from the positive pole of the 4-cell battery B_1, through the lamps L_1, and L_2, through the battery B_2, and back through B_1 to its positive terminal again.

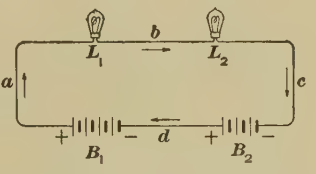

FIG. 4

From a careful study of Fig. 4, it will be obvious that: (1) *The current is the same in all parts*

of a series circuit; and (2) that, as the current overcomes the resistance of each part of the circuit successively, *the total resistance of a series circuit is equal to the sum of the resistances of its various parts.*

46. Electromotive Forces in Series.—Electromotive forces to assist one another must act in the same direction. If, therefore, it is desired to increase the electromotive force of a circuit by adding one or more cells, they must be connected so that the direction of their E.M.F.'s is the same as that of the original source of E.M.F., which is from its positive terminal through the external circuit to its negative terminal. Hence, the positive terminal of each cell must be connected, directly or indirectly, to the negative terminal of the next, as shown in Fig. 4.

In a series circuit in which all sources of E.M.F. are acting in the same direction, the total E.M.F. applied to the circuit is equal to the sum of the electromotive forces in the circuit.

EXAMPLE.—In Fig. 4, each cell of the two batteries B_1 and B_2 gives an electromotive force of 1·1 volts; calculate the total E.M.F. applied to the circuit.

SOLUTION.—As the 4 cells of B_1 and the 3 cells of B_2 all act in the same direction, the total E.M.F. applied to the circuit is equal to the sum of the E.M.F.'s of the cells. But as the E.M.F. of each cell is the same,

the total E.M.F. $= 7 \times 1{\cdot}1 = 7{\cdot}7$ volts. Ans.

47. If the battery B_2 in Fig. 4 were to be connected in the opposite way to that shown, with its negative pole connected to the negative pole of B_1 and its positive terminal connected, through the lamps, to the positive terminal of B_1, the E.M.F.'s of the batteries would be opposed to one another. If each cell gave an E.M.F. of 1·1 volts, the total E.M.F. applied to the circuit would only equal the difference of the E.M.F.'s of the two batteries; that is, $4{\cdot}4 - 3{\cdot}3$, or 1·1 volts.

In a series circuit containing electromotive forces opposed to one another, the total electromotive force applied to the circuit is equal to the difference between the sum of the electromotive forces acting in one direction and the sum of the electromotive forces acting in the other direction.

EXAMPLE.—In a circuit arranged as shown in Fig. 4, the following values obtain: E.M.F. of each cell, 2 volts; internal resistance of each

cell, 2 ohms; resistance of lamp L_1, 3 ohms; resistance of lamp L_2, 4 ohms; and resistance of all connecting wires, ·5 ohm. Calculate (*a*) the total E.M.F. applied to the circuit, (*b*) the total resistance of the circuit, (*c*) the current in the circuit, and (*d*) the power absorbed in the circuit.

SOLUTION.—(*a*) By Art. **46**, as all the E.M.F.'s are acting in the same direction, the total E.M.F. applied to the circuit is equal to their sum. As there are seven E.M.F.'s, each of 2 volts,

$$\text{the total E.M.F.} = 7 \times 2 = 14 \text{ volts.} \quad \text{Ans.}$$

(*b*) By Art. **45** the total resistance in the circuit is equal to the sum of the resistances in the circuit. As the internal resistance of each cell is 2 ohms, the resistance of the two batteries together is 14 ohms; the resistances of the lamps and connecting wires added together make 7·5 ohms, so that the total resistance of the circuit is 21·5 ohms. Ans.

(*c*) By Ohm's law the current in the circuit is equal to the total E.M.F. divided by the total resistance

$$\frac{14}{21{\cdot}5} = {\cdot}651 \text{ ampere.} \quad \text{Ans.}$$

(*d*) By Art. **37** the power absorbed in the circuit is equal to the total E.M.F. multiplied by the current in the circuit

$$14 \times {\cdot}651 = 9{\cdot}114 \text{ watts.} \quad \text{Ans.}$$

EXAMPLE FOR PRACTICE

48. Fig. 5 represents two batteries B_1 and B_2 of 3 and 7 cells, respectively, and a lamp L connected in series as shown. The E.M.F. of each cell is 1·1 volts; the internal resistance of each cell 3 ohms; the resistance of the lamp 10 ohms; and the resistance of the connecting wire 1 ohm. Calculate (*a*) the total E.M.F. applied to the circuit; (*b*) the total resistance of the circuit; (*c*) the current in the circuit; and (*d*) the power absorbed in the circuit.

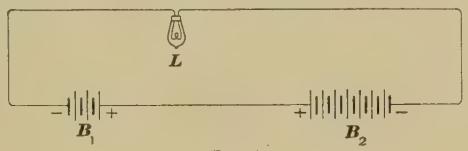

FIG. 5

Ans. (*a*) 4·4 volts; (*b*) 41 ohms; (*c*) ·11 ampere, nearly; (*d*) ·48 watt, nearly

PARALLEL CIRCUITS

49. Parallel, or Multiple, Connections.—A circuit divided into two or more branches, each branch transmitting part of the current, is a **divided circuit**; the conductors forming these

branches are said to be connected in parallel or multiple. Each branch taken separately is called a shunt. Such a circuit is shown in Fig. 6. The conductors r_1 and r_2 are the two branches into which the portion $a\,b$ of the circuit is divided. The conductors r_1 and r_2 are said to be connected in parallel or multiple, and r_1 is said to shunt r_2, or r_2 is said to shunt r_1. The total current C divides at a, the separate currents flow simultaneously through the two branches, the portion C_1 flowing through r_1, and C_2 through r_2, uniting again at b. Any number of additional branches may be provided.

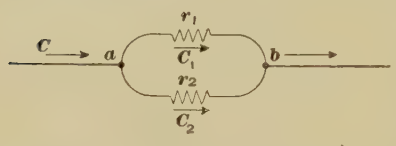

FIG. 6

In dealing with divided circuits it is necessary that the meaning of conductivity should be thoroughly understood. In Art. 5 it is stated that conductivity is the reciprocal of resistance. Therefore, since the conductivity is greater the less the resistance, the conductivity may be defined as being equal to $\frac{1}{R}$.

50. Current in Parallel Circuits.—From what has been said in the previous articles it will be seen that, *in a parallel circuit, the current distributes itself in the branches in direct proportion to their conductivities and in inverse ratio to their resistances. The sum of the currents in the branches equals the total or main current.* In Fig. 6 the conductivities of the two branches are $\frac{1}{r_1}$ and $\frac{1}{r_2}$, respectively.

Therefore, $$C_1 : C_2 :: \frac{1}{r_1} : \frac{1}{r_2}, \text{ or } \frac{C_1}{C_2} = \frac{r_2}{r_1}$$

EXAMPLE.—Given $C = 60$ amperes; $r_1 = 2$ ohms; $r_2 = 3$ ohms. Find C_1 and C_2.

SOLUTION.— $\frac{C_1}{C_2} = \frac{r_2}{r_1}$, or $\frac{C_1}{C_2} = \frac{3}{2}$, or $C_1 = \frac{3\,C_2}{2}$.

But $C_1 + C_2 = 60$, or $C_1 = 60 - C_2$. Substituting for the value of C_1 gives $60 - C_2 = \frac{3\,C_2}{2}$. Clearing of fractions and transposing gives $5\,C_2 = 120$, or

$C_2 = 24$ amperes. Ans.

$C_1 = 60 - 24 = 36$ amperes. Ans.

51. Resistances in Parallel.—It is clear that two conductors in parallel will conduct an electric current more readily than one alone; that is, their *joint* conductivity is greater than either of their separate conductivities taken alone. This being the case, their resistances must follow the inverse law; that is, the *joint* resistance of two conductors in parallel must be less than either of their separate resistances taken alone.

Rule.—*The joint resistance of two conductors in parallel is equal to the product of their separate resistances divided by the sum of their separate resistances.*

Let R'' = total resistance;
r_1 = resistance of one branch;
r_2 = resistance of other branch.

$$R'' = \frac{r_1 r_2}{r_1 + r_2}$$

EXAMPLE.—In Fig. 6, $r_1 = 4$ ohms, $r_2 = 6$ ohms, and $C = 30$ amperes. Find C_1 and C_2 in the separate branches and the joint resistance of the branches from *a* to *b*.

SOLUTION.— $\frac{C_1}{C_2} = \frac{6}{4}$, or $C_1 = \frac{6C_2}{4}$.

But $C_1 + C_2 = 30$, or $C_1 = 30 - C_2$; substituting, $30 - C_2 = \frac{6C_2}{4}$.

Clearing of fractions and transposing gives $10C_2 = 120$
$C_2 = 12$ amperes. Ans.
$C_1 = 30 - 12 = 18$ amperes. Ans.

By the formula $R'' = \frac{r_1 r_2}{r_1 + r_2}$

$$R'' = \frac{4 \times 6}{4 + 6} = 2{\cdot}4 \text{ ohms.} \quad \text{Ans.}$$

52. Fig. 7 represents a divided circuit of three branches. Let r_1, r_2, and r_3 equal the separate resistances of the three branches, respectively, then, $\frac{1}{r_1}$, $\frac{1}{r_2}$, and $\frac{1}{r_3}$ represent the separate conductivities of the three branches, respectively.

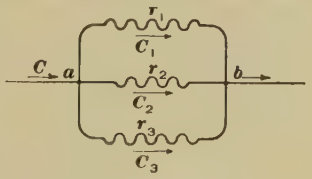

FIG. 7

Their joint conductivity $= \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} = \frac{r_2 r_3 + r_1 r_3 + r_1 r_2}{r_1 r_2 r_3}$.

Since the joint resistance is the reciprocal of the joint conductivity, then, $R''' = 1 \div \frac{r_2 r_3 + r_1 r_3 + r_1 r_2}{r_1 r_2 r_3} = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}$, the joint resistance of the three branches in parallel from a to b.

Rule.—*The joint resistance of three or more conductors in parallel is equal to the reciprocal of their joint conductivity.*

Example.—In Fig. 7, $r_1 = 5$ ohms, $r_2 = 10$ ohms, and $r_3 = 20$ ohms. Find their joint resistance from a to b.

Solution.—By the formula

$$R''' = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2} = \frac{5 \times 10 \times 20}{(10 \times 20) + (5 \times 20) + (5 \times 10)} = \frac{1{,}000}{350}$$
$$= 2\tfrac{6}{7} \text{ ohms.} \quad \text{Ans.}$$

53. Electromotive Forces in Parallel.—A battery of voltaic cells is said to be connected in multiple, or parallel, when the positive terminals of all the cells are connected to end a of the circuit, and all the negative terminals are connected to the other end b of the circuit, as shown in Fig. 8.

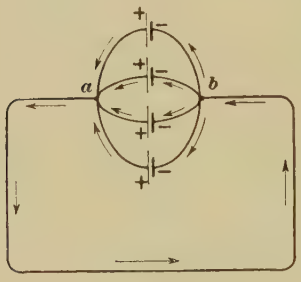

Fig. 8

When so connected, all the positive terminals have the same potential and all the negative terminals have the same potential; hence, joining cells together in parallel does not increase the electromotive force above that of one cell. A number of cells that are joined in parallel is really the equivalent of one large cell that has exposed to the electrolyte a plate-surface area equal to the sum of the exposed areas of all the plates of the group. There is no increase of electromotive force, but the current capacity increases with the increase of exposed plate surface because the resistance of cells, as shown in Art. **51**, is less.

Dynamos are also connected in parallel to increase the current output; the current output of the machines so connected is the sum of the outputs of all the machines, but the electromotive force is not increased.

54. In any divided circuit, the difference of potential between where the branches divide and where they unite is equal to the product of the sum of the currents in the separate branches and their joint resistance in parallel. For example, if the currents in the three branches, Fig. 7, are 16, 8, and 4 amperes, respectively, and the joint resistance from a to b is $2\frac{6}{7}$ ohms, then the difference of potential between a and b is $(16 + 8 + 4) \times 2\frac{6}{7} = 28 \times \frac{20}{7}$ $= 80$ volts.

55. The separate currents in the branches of a divided circuit can be determined by finding the difference of potential between where the branches divide and where they unite, and dividing the result by the separate resistance of each branch. For example, in Fig. 7, assume that the difference of potential between a and b is 80 volts, and that the separate resistances of the three branches are 5, 10, and 20 ohms, respectively. Then, the current in the first branch is $\frac{80}{5} = 16$ amperes ; in the second, $\frac{80}{10} = 8$ amperes ; and in the third, $\frac{80}{20} = 4$ amperes.

56. The separate resistances of the branches of a divided circuit can be determined by finding the difference of potential between where the branches divide and where they unite, and dividing the result by the separate currents in each branch. For example, in Fig. 7, assume the difference of potential between a and b to be 80 volts, and the currents in the separate branches to be 16, 8, and 4 amperes, respectively. Then, the resistance of the first branch is $\frac{80}{16} = 5$ ohms ; of the second, $\frac{80}{8} = 10$ ohms ; and the third, $\frac{80}{4} = 20$ ohms.

EXAMPLES FOR PRACTICE

57. 1. The separate resistances of two branches of a divided circuit are 13 and 29 ohms, respectively. Find their joint resistance in parallel.

Ans. 9 ohms, nearly

2. The sum of the currents in two branches of a divided circuit is 28 amperes. If the separate resistance of branch a is 7 ohms and the separate resistance of b is 4 ohms, what is the joint resistance in parallel and the separate currents in each branch ?

Ans. { Joint resistance, 2·545 ohms
Current in branch a, 10·18 amperes
Current in branch b, 17·81 amperes

3. The separate resistances of three branches a, b, and c of a divided circuit are 2, 3, and 4 ohms. If the sum of the currents in the three branches is 26 amperes, what is the separate current in each branch ?

Ans. { 12 amperes in a
8 amperes in b
6 amperes in c

---

58. Series-Parallel or Multiple-Series Connections.—When the series and multiple connections are combined, the arrangement is known as **series-parallel** or **multiple-series.** Fig. 9 shows a battery connected in series-parallel or multiple-series; this is accomplished by joining several groups of cells in multiple or parallel, the cells in each group being connected in series. When so connected, the total electromotive force of the group is equal to the electromotive force of one series-group.

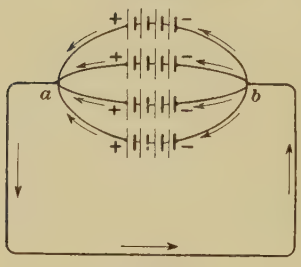

FIG. 9

EXAMPLE.—If the electromotive force of each cell, Fig. 9, is 1·8 volts, what is the total electromotive force of the battery ?

SOLUTION.—There are four parallel groups, each group consisting of four cells joined in series; hence, the total E.M.F. of the group is equal to the E.M.F. of one series-row, Arts. **46** and **53,** which is $4 \times 1{\cdot}8 = 7{\cdot}2$ volts. Ans.

ELECTRIC WIRING AND BELLS

(PART 2)

ELECTRIC-LIGHT AND POWER WIRING

MATERIALS AND WORKMANSHIP

INTRODUCTION

1. The subject of interior wiring includes a study of the various methods for supplying electric current to lamps, motors, etc., also to bells and other minor appliances operated by electricity.

In electric wiring, the object is to conduct electricity to the device to be operated ; but this should be done in such a manner that danger, unsatisfactory operation, and waste will be avoided.

The following requirements should be complied with in every electric installation : Safety, satisfactory operation, convenience, neatness, and economy. The architect and electrician should therefore understand the sources of danger in the use of electricity, the precautions necessary to avoid these dangers, as well as how to make the work satisfactory in other respects and profitable.

2. Wiring Rules of the Institution of Electrical Engineers. When installed in a proper manner, electric light is the safest artificial illuminant, and is recommended by the fire insurance companies in preference to any other. If, however, the installation is badly designed or carelessly executed, the possibility of failure, and even fire, is great.

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In order to fix a standard of minimum safety and to secure uniformity of practice, the Institution of Electrical Engineers have drawn up a set of rules relating to the arrangement of installations and to the construction of the materials used.

These rules are most important, and the architect should satisfy himself that installations carried out under his charge comply with them in every respect.

Many of the rules are quoted in the following pages in describing the different branches of wiring work to which they apply.

One or two of the electric supply and fire insurance companies issue special rules of their own, and the architect should communicate with the companies concerned before starting the work. Installations in public buildings are also subject to special regulations, copies of which may be secured on application to those controlling the premises.

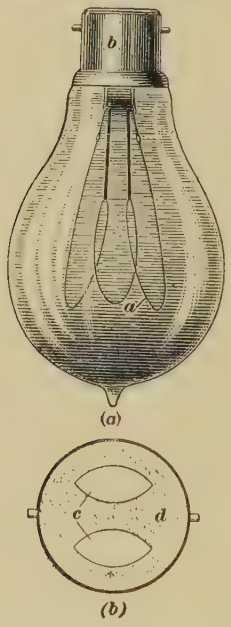


FIG. 1

INCANDESCENT ELECTRIC LAMPS

3. Metallic- and Carbon-Filament Lamps. The incandescent electric lamp, illustrated in Fig. 1 (*a*), consists of the **filament,** a fine thread or loop *a* of either carbon or one of the rare metals, tantalum or tungsten, supported in a glass globe from which the air has been exhausted. The globe is mounted on a brass cap *b* which, in Great Britain, usually takes the form shown in Fig. 1, and is known as the **b.c.,** or **bayonet cap.** A plan of this cap is shown in Fig. 1 (*b*). The brass collar is filled with plaster of Paris *d*, in which are inserted the two contacts *c*, which are connected by either platinum or copper wires with the filament.

Incandescent carbon lamps are made for all voltages, from 50 to 250, and are rated in **candlepower,** abbreviated **c.p.**; that is, a lamp that will give as much light as 16 spermaceti candles

of standard dimensions is called a 16-candlepower lamp. They are made in sizes from 1 to 500 candlepower, those in most general use being 5, 8, 16, 25, and 32 candlepower.

Metallic-filament lamps are at present considerably more expensive and more fragile than carbon-filament lamps, and are not obtainable in candlepowers lower than 16 in the 100- to 120-volt lamps and 32 in the 200- to 250-volt lamps; they furnish, however, the light at a greater economy. Both carbon- and metallic-filament lamps are made in many shapes and sizes.

4. Efficiency of Electric Lamps.—The ratio of the power absorbed, in watts, to the light given out, in standard candlepower, is usually taken as the **efficiency** of the lamp; it enters largely into wiring calculations, and should be thoroughly understood. While this definition of efficiency is still in general use, it does not, in reality, represent the efficiency of a lamp, but rather its inefficiency. It is clear that, if one lamp requires 3 watts per candlepower and another only 2 watts, the latter is the more efficient of the two. But according to the definition given it would be less efficient.

The average efficiencies of modern incandescent lamps are as follows: Ordinary carbon filament, 3·5 watts per candlepower; tantalum lamps, 1·7 watts per candlepower; tungsten lamps, 1·2 watts per candlepower.

EXAMPLE.—Calculate the current required by twenty 16-candlepower carbon-filament lamps on a 200-volt circuit, if the efficiency of the lamps is 3·5 watts per candlepower.

SOLUTION.—The power absorbed by each lamp is equal to its candlepower multiplied by the number of watts required per candlepower, or $16 \times 3{\cdot}5 = 56$ watts; hence, the total power absorbed $= 20 \times 56 = 1{,}120$ watts, and as amperes $= \frac{\text{watts}}{\text{volts}}$,

$$\text{the current required in amperes} = \frac{1{,}120}{200} = 5{\cdot}6. \quad \text{Ans.}$$

ELECTRIC CONDUCTORS

5. Gauge Numbers.—Wires for electric conductors are made with certain standard diameters, each diameter being designated by a *gauge number*. The system in general use in Great Britain

is known as the Imperial Standard Wire Gauge, abbreviated S.W.G.

In this system the gauge numbers run inversely to the cross-sectional areas, that is, the larger the wire the smaller its gauge number ; for instance, a No. 20 wire is larger than a No. 22.

6. Wires and Cables.—Strictly speaking, all single conductors should be known as wires, and those consisting of more than one

TABLE I

CROSS-SECTIONAL AREA, MAXIMUM CARRYING CAPACITY, AND RESISTANCE OF CONDUCTORS

Size and Number of Strands, Standard Wire Gauge	Cross-Sectional Area Square Inch	Maximum Safe Carrying Capacity		Resistance, in Ohms, Per 1,000 Yards
		Amperes at 1,000 Amperes Per Square Inch	Amperes at Institution of Electrical Engineers Standard	
1/18	·00181	1·81	4·2	13·29
3/22	·00181	1·81	4·2	13·27
3/21	·00237	2·37	5·3	10·16
3/20	·00299	2·99	6·44	8·03
7/22	·00424	4·24	8·54	5·67
7/21	·00554	5·54	10·63	4·34
7/20	·00701	7·01	12·9	3·43
7/18	·0125	12·5	20·68	1·93
19/20	·019	19	29·23	1·27
7/16	·022	22	33·12	1·09
19/18	·034	34	46·85	·712
19/16	·06	60	75·06	·401
19/14	·094	94	108	·2565
37/16	·117	117	129	·2059
37/14	·183	183	187	·1318

wire, or strand, as **stranded cables.** This distinction is, however, not strictly observed, a conductor of one wire only being sometimes called a cable, and a stranded cable, a wire. Cables consisting of at least three wires should be used wherever possible, and no single conductor smaller than No. 18 S.W.G. is allowed for interior wiring. For heavy currents it is better to use a

conductor composed of a number of wires of a smaller gauge than one composed of a few wires of a large gauge, on account of the greater flexibility of the cable with smaller wires.

Cables are usually made up of 3, 7, 19, 37, or 61 wires. The first column in Table I gives a list of the sizes generally in use for currents up to about 200 amperes. The numerators of the fractions in Table I indicate how many wires of the sizes shown by the denominators are to be used. Thus, 3/20 means that three number 20 wires are to be used. In column 2 of the table are given the combined sectional areas of the wires constituting a cable. Column 3 gives the carrying capacity of the various cables, allowing 1,000 amperes per square inch of sectional area. In column 4 are given the carrying capacities of the cables according to the standard adopted by the Institution of Electrical Engineers. As seen, the allowable amperages are greater in this case than those given in column 3. Column 5 gives the resistance in ohms of any of the cables for a length of 1,000 yards.

7. Insulation.—The properties of the material used for insulating a cable are just as important as those of the conductor itself. The requirements of a good cable-insulating material are :

1. It must prevent leakage of the current and consequent loss of energy.

2. It must be strong and tough and yet flexible, so that it may be easily bent without damage.

3. It must be impervious to moisture, as water is to some extent a conductor, and more failures are traceable to dampness than to any other cause.

The material which most nearly fulfils these conditions is pure india-rubber, but it is somewhat easily damaged and perishes rather quickly on exposure to the atmosphere. If, however, the rubber is put through a process known as *vulcanizing*, it loses little of its insulating property, but gains in strength and durability.

8. The Construction of Electric Cables.—The copper conductor is first tinned, to prevent the harmful action of any sulphur which may be present in the vulcanized rubber. It is then wrapped with two thin coatings of pure rubber, laid on

spirally in opposite directions to cover the joints, followed by a further thin layer of rubber containing a little antimony or similar substance. Over this is laid a *jacket* of vulcanized india-rubber. The whole is then vulcanized together at a temperature of about 140° C.; in this process the three coatings become one homogeneous envelope. The cable is finally protected with a layer of strong tape and a covering of cotton braid thoroughly soaked in ozocerite, or other preservative compound. Fig. 2 illustrates a seven-stranded rubber insulated cable: *w* is the conductor proper, *r* the pure and vulcanized india-rubber insulator, *g* the protective tape, and *b* the braid.

FIG. 2

9. Grading of Cables.—Electric cables are graded according to the resistance per mile of their insulation tested immediately after 24 hours' immersion in water. They are made commercially with an insulation resistance of from 300 to 5,000 megohms per mile, the grades usually specified being 300, 600, and 2,500 megohms per mile. As the difference in price between the 300- and 600-megohm grades is small, the use of the former is not recommended; the latter may, however, be safely employed in dry places. The 2,500-megohm class should be specified in all cases where the installation is likely to be subjected to any dampness.

Cable is usually delivered in bound coils, 110 yards long, each coil bearing a label with the maker's name and the grade of the wire. Architects are strongly advised to insist that all cables shall be made by a well-known manufacturer and be delivered on the site in the original coils, with labels intact.

10. Carrying Capacity of Conductors.—It has been pointed out in *Electric Wiring and Bells*, Part 1, that when a current passes through a conductor a certain amount of power is wasted in overcoming the resistance of the conductor, and that this waste, or loss, is proportional both to the resistance of the conductor and to the square of the current. If, therefore, a

heavy current is forced through a conductor of comparatively high resistance, not only are the losses in transmission very great, but the heating of the conductor may be so excessive as to become dangerous. In order to prevent these losses and the danger of overheating, it is necessary to fix a standard for each size of conductor, giving the safe current which may be conveyed by it.

11. Two sets of standards are in use in Great Britain ; the first, known as the **thousand-ampere rule,** limits the current which may safely be carried by any conductor to the proportion of 1,000 amperes per square inch of cross-sectional area. The second set of standards has been drawn up by the Institution of Electrical Engineers, abbreviated I.E.E., and though it allows larger currents than the thousand-ampere rule for the smaller sizes of wire, it may safely be adopted for conductors of short lengths at ordinary temperatures. If the cables are subjected to a high temperature or are unusually long, the sizes equal to, or even larger than, those given by the thousand-ampere rule should be used. The carrying capacities of the different cables are given for both standards in columns 3 and 4 of Table I.

12. Drop of Potential in Conductors.—In order to prevent undue transmission losses, it is usual to specify that the drop of potential in a conductor running between the point of intake, that is, the point from which the supply is taken, and the point supplied shall not exceed a definite percentage, usually 2 per cent. This refers also to the conductor in which the current returns to the source of supply. It will therefore simplify matters, if the distance between the intake and the point supplied, that is, the lead, is multiplied by 2, the result being the sum of the lead and return wires. If the circuit is a long one, the loss of potential in a conductor, even while carrying a current less than its safe maximum, may exceed this limit, and it is therefore necessary to be able to calculate the size of conductor required for a specified current and drop in pressure. This calculation can be easily made by referring to column 5 of Table I, which gives the resistance in ohms, per 1,000 yards of the different conductors.

EXAMPLE.—A group of lamps requiring a current of 10 amperes is situated 50 yards from the source of supply, and the permissible drop is 4 volts. Find the size wire that should be employed.

SOLUTION.—The total length of conductor, lead and return, is $2 \times 50 = 100$ yd.; the maximum resistance allowable in this conductor is, by Ohm's law,

$$R = \frac{E}{C} = \frac{4}{10} = \cdot 4 \text{ ohm}$$

The maximum resistance per 1,000 yd. must therefore not exceed $\frac{\cdot 4}{100} \times 1{,}000 = 4$ ohms. On reference to column 5, Table I, it is seen that 7/20 is the smallest cable having a resistance of less than 4 ohms per 1,000 yd., and as its carrying capacity at the Institution of Electrical Engineers standard is greater than 10 amperes, this size would be the one selected. Ans.

EXAMPLE FOR PRACTICE

13. A motor requiring a current of 30 amperes at full load is situated 220 yards from the source of supply. The drop in volts on the conductors is not to exceed 5 volts; calculate the size of the necessary cable.

Ans. 19/14

FLEXIBLE CONDUCTORS AND JOINTS

14. Flexible Conductors.—Special conductors used for connecting pendants, hand lamps, table standards, and similar fittings are known as **flexible conductors.** They are thinner and more ornamental than ordinary cables and consist of two small conductors twisted together. Each conductor is usually composed of 35 or 70 strands of No. 40 S.W.G. wire; these are covered with a wrapping of cotton and then provided with a layer of pure rubber, the whole being braided with coloured silk or glacé cotton.

For use in damp places and where an ordinary flexible conductor would be liable to damage a special form known as **workshop flexible** is made. In this form the two conductors are wrapped with a thick layer of cotton and surrounded by a cotton braiding, the complete conductor being then immersed in melted black ozocerite.

15. Joints.—In a properly designed installation joints should very rarely be necessary, and the latest edition of the Rules of

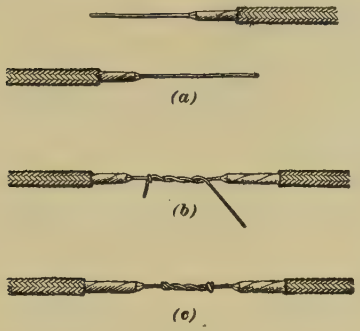


FIG. 3

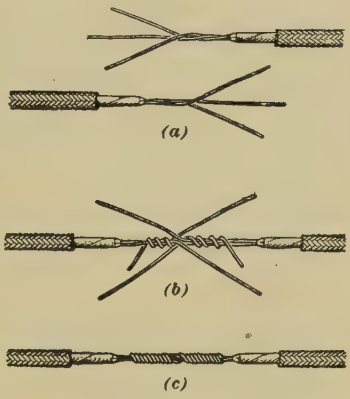


FIG. 4

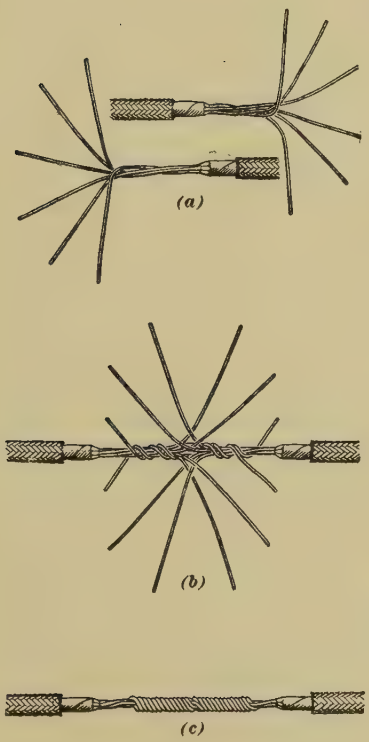


FIG 5

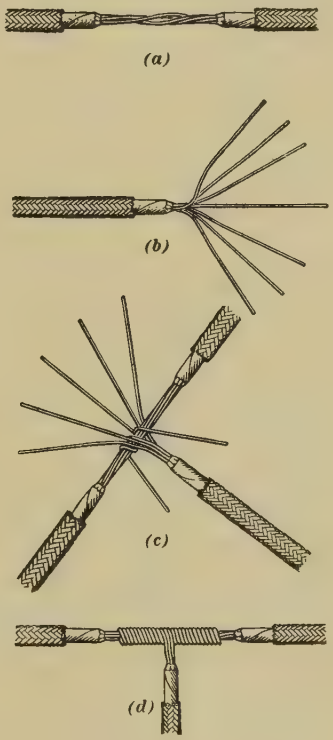


FIG. 6

the Institution of Electrical Engineers states that "Joints constitute a source of weakness and should be avoided whenever possible." When joints are absolutely necessary, the greatest care should be taken in making them, as trouble is more likely to occur at these points than at any other. *A good joint should be mechanically and electrically perfect*, that is, there must not be the slightest danger of the separation of the conductors at the joint, and its conductivity must be at least equal to that of an equal length of unjointed conductor.

16. Methods of Making Joints.—Carefully pare back the insulation from the copper, so as to leave sufficient bare conductor for thorough contact between the two cables. Strip back the braid and tape from the rubber for about $2\frac{1}{2}$ inches and the braid back from the tape for another inch beyond this. The two cable ends to be joined will then appear as in Fig. 3 (*a*). The wire should be scraped until it is clean and bright, and then the bright portions twisted together, in the manner shown in view (*b*), the finished joint being shown in (*c*). The utmost cleanliness should be observed in all the processes of joint making.

17. Figs. 4 and 5 show similar joints with three- and seven-stranded cables, the method followed being similar to that shown in Fig. 3, the whole process being easily seen from the various views. In each of these figures the views (*a*) show the ends of the bared wires ready for connection, views (*b*) the ends partly twisted together, and views (*c*) the finished joints. In Fig. 5 (*a*) the central wire of the cable is cut short at the point where the outer wires are bent. Figs. 3, 4, and 5 each represent a *straight through* joint, that is, a joint which serves the purpose of joining one conductor to another, so as to form one continuous conductor. Fig. 6 illustrates the method of making a tee joint on a seven-stranded cable. In this case one conductor is to be joined at right angles to another conductor. The conductor to which the branch is to be joined is first bared and slightly untwisted, as shown at (*a*). The other conductor, prepared as shown at (*b*), has then some of its strands inserted through the openings of the straight conductor, as shown at (*c*),

after which the loose strands are twisted round the latter in the manner shown, the finished joint being shown in view (*d*).

The methods adopted in joining large cables are very similar to those shown, some of the outer strands, however, are cut away in order not to unduly increase the size of the conductor at the joint. When the joint has been made, it should be thoroughly soldered. Soldering fluids containing acid or any other corrosive substance must not be used. Resin is the only permissible flux.

18. Insulating the Joints.—The insulation of the joint should be as nearly as possible equal to that of the cable. The joint is first thoroughly cleaned with a clean dry cloth and the rubber insulation cut to a cone shape. A little rubber solution is applied and a pure rubber strip laid spirally on, so as to form a layer up to the tapered ends of the rubber. After another thin application of solution, tape is wound on in the reverse direction, and this is repeated until the diameter of the joint is about equal to that of the rest of the wire. The joint is finally protected by several layers of a prepared waterproof tape and the whole varnished.

19. The Connection of Cables.—If conductors are not properly connected at their terminals, the conductivity of the junction is lower than that of the cable and serious heating may result.

The cable should first be stripped back, as shown in Fig. 3, not baring more of the copper than is necessary to make a proper connection with the terminal, and the strands well twisted together. In the sizes smaller than 7/22 S.W.G. it is not necessary to join the strands by soldering.

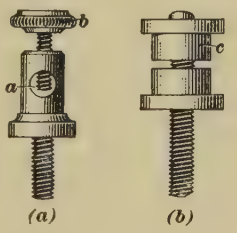


Fig. 7

Most electrical apparatus is fitted with terminals similar in principle to those shown in Fig. 7 (*a*) and (*b*). In Fig. 7 (*a*) the end of the conductor is pushed into the hole *a* and the binding screw *b* is screwed down firmly on it. In Fig. 7 (*b*) the end of the conductor is bent into a hook and placed under the nut *c*, which is screwed down on it.

The strands of cables larger than 7/22 S.W.G. should be soldered together and then sweated into a terminal or *lug* similar to that shown at *a* in Fig. 8. The lug is placed under the nut of a terminal similar to Fig. 7 (*b*), the nut *c* being first removed so that the hole *b* in the lug can be passed over the threaded stem of the terminal.

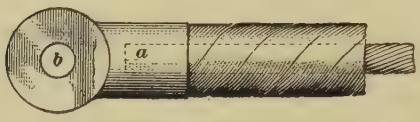


Fig. 8

SWITCHES

20. Function of a Switch. — A switch is usually a simple piece of apparatus whereby one or both of the conductors of a circuit can be quickly and easily divided or rejoined, thus breaking or closing the circuit. The points of the switch at which the separation actually takes place are known as the *contacts*. The function of a switch is to stop or divert the flow of an electric current in much the same way as that of a water tap is to check or divert the flow of water in a system of pipes.

21. Arcing at Switches.—As the division of a conductor takes place, the resistance at the point of separation increases enormously, and if the circuit is conveying a current of some strength the heat generated in overcoming this resistance may be so great as to turn the metal of the contacts into vapour. This vapour, which is a moderately good conductor, is in the form of a flame, and is technically known as an **arc.** It will maintain the current between the contacts until the gap between them, and therefore the resistance, becomes great.

Pronounced arcing at switches is objectionable as it not only prevents the instantaneous interruption of the current, but it burns away and ultimately destroys the contacts between which the arc occurs.

If the separation of the conductor is effected very rapidly, the resistance increases from a negligible value to infinity almost instantaneously, and there is no time for sufficient heat to be generated to form a destructive arc. Most modern switches are fitted with some arrangement which secures this quick break.

22. Requirements of a Good Switch.—A good switch should fulfil the following requirements :

1. *Ample carrying capacity* of all parts, so that no heating will occur. The current in the copper portions of a switch should never exceed 800 amperes per square inch of cross-sectional area in the fixed portions, or 100 amperes per square inch at the contacts.

2. *Quick break,* in order to prevent the formation of arcs.

3. *Positive break ;* that is, it must be impossible to leave the switch in any other position than in perfect contact or completely open.

4. It must be mounted on a good insulator which is impervious to moisture, in order to prevent leakage.

5. The handle and cover of the switch must be completely insulated from all current-carrying parts, in order to prevent shocks to persons handling the switch for ordinary purposes.

23. Main Switches.—Switches may be roughly divided into two classes : *Main switches* and *sub-switches.* Switches which are arranged to control a complete circuit or installation are called **main switches.** These are usually arranged to break the circuit on both conductors simultaneously, thus completely cutting off the current from the apparatus they control : when so arranged they are known as **double-pole switches.** They may also break the circuit on one wire only and are then known as **single-pole switches.** Main switches should be placed as close as possible to the source of supply, whether dynamo or street mains.

24. Knife Switch.—A good example of a modern single-pole switch for currents of more than 10 amperes is illustrated in Fig. 9. This type is known as a **knife switch.** One of the conductors feeding the circuit, which the switch is to control, is cut at a convenient position for the fixing of the switch and the ends trimmed and sweated into the lugs l', l'', as described in Art. **19.** When the switch is in the position shown, that is, *closed,* it may be assumed that the current enters at the lug l' and passes consecutively through the bolt a', the contact c', the blades b and d, the hinged contact c'' with pin h, the bolt a'' back to the circuit through the lug l''.

The switch shown in Fig. 9 is of the *twin-blade* type. The two blades *b* and *d*, though hinged concentrically at *h*, are entirely separate plates of metal simply held together by the spiral spring *t*. The insulated handle *e* is attached to blade *b*. When it is desired to open the circuit the blade *b* is pulled out of the grip of the contact *c'* by the handle *e*, but the friction of the contact *c'* retains the blade *d* until the tension on the spring *t* is sufficient to overcome the friction of the contact, when it flies off with great rapidity, thus interrupting the circuit without any appreciable arc. In practice, the switch would be mounted on a slate, marble, or porcelain base *s*, shown dotted in the figure, and would be provided with a teak case with glazed front, lock and key, if in a dry situation, or a water-tight ironclad case if subject to the least dampness.

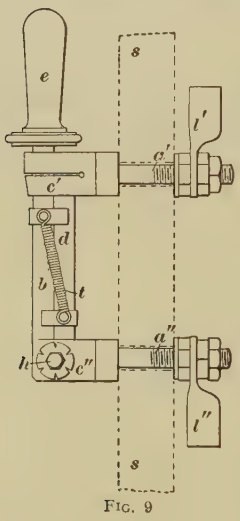
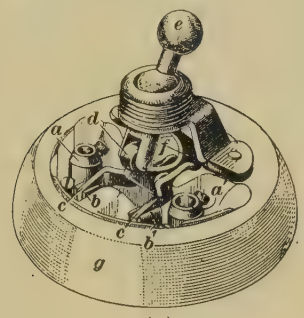


FIG. 9

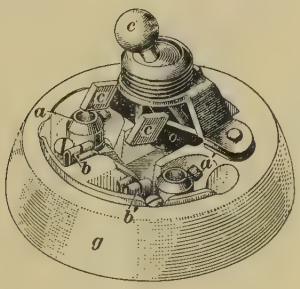
25. A double-pole switch of the knife type simply consists of two distinct switches on separate slate bases mounted in one case, the opposite poles being separated by an insulated fillet, or strip. The handles are connected with a bar of insulating material, in order to make the break on both conductors simultaneous.

26. Sub-Switches.—**Sub-switches** are usually small switches fixed in a convenient position near the individual lamp or group of lamps they are intended to control. As their purpose is not protective, but simply to switch on or off the lights single-pole switches are generally employed. The type of sub-switch most generally in use is known as the **tumbler switch.** An excellent example of this type is illustrated in Fig. 10 (*a*), (*b*), and (*c*). The wire to the light, or group of lights, it is desired to control is cut and connected to the terminals *a* and *a'* in Fig. 10 as described in Art. **19.** Terminal *a* is directly connected to contact *b* and terminal *a'* to contact *b'*. Fig. 10 (*a*) shows the

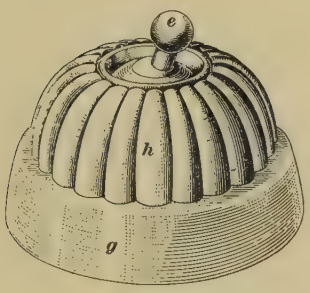
switch in an *on*-position, connection between the terminals being made by the blades *c*, *c*. By comparing this drawing with Fig. 10 (*b*), which shows the switch in an *off*-position, a good idea of the working can be obtained. The roller *d*, Fig. 10 (*a*), is connected directly to an extension of the handle *e* and actuates the insulated cam-shaped plate *f*, which in turn forces the blades *c* into, or out of, the contacts *b* and *b'*. Quick and positive break is obtained by a spiral spring, not shown in drawing, which tends to keep the switch in an off-position. The working parts of the switch are mounted on a porcelain base *g* and are usually provided with a fluted polished-brass cover *h*, as shown in Fig. 10 (*c*).



(*a*)



(*b*)



(*c*)

FIG. 10

27. Two-Way Tumbler Switch. A special form of switch which is very useful in certain situations is illustrated in Fig. 11. It is known

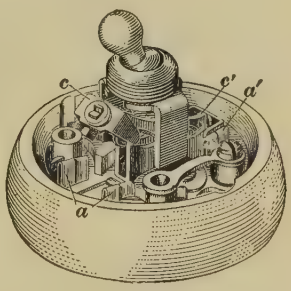


FIG. 11

as a **two-way tumbler switch**, and by using two of them a light, or group of lights, can be switched on and off at either of two positions; for instance, the light in a bedroom can be switched

on at the door on entering and switched off from the bed. The general construction is very similar to the ordinary switch illustrated in Fig. 10 (*a*), but in this case there are two pairs of contacts *a*, *a'*, in Fig. 11, and the blades *c*, *c'*, which alternately make connection with one or the other of these contacts, form

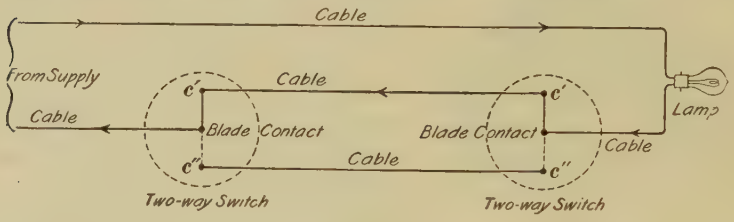


FIG. 12

a third terminal. Fig. 12 shows the connections for two of these switches controlling one lamp.

28. **Two-Way Double-Pole Knife Switch.**—A **two-way double-pole knife switch** is shown in Fig. 13, in which *a* is the handle and *b*, *b'* the two blades. The contact jaws for the dynamo circuit are marked *c*, and those for the public supply circuit *c'*. The set of jaws for the installation are *d*, *d'*. To prevent arcing across the jaws an insulating shield *e* is placed between the two slate panels, one of which is indicated by letter *f*. By means of this switch an installation can be connected at will to either of two distinct supplies. For instance, a large house might take its power from the street mains during the day and from its own dynamo at night. Fig. 14 shows the arrangement

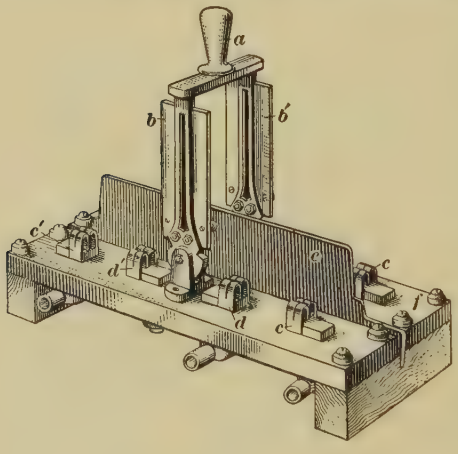


FIG. 13

of connections in such a case. Fig. 15 shows a switch, with removable key *a*, for use in public buildings and situations where it is desired that the lights shall only be controlled by an authorized person.

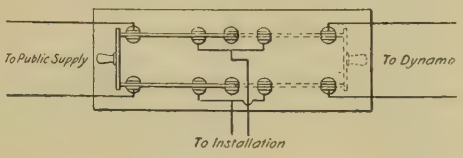


Fig. 14

29. The Position of Switches.—One of the great advantages of the electric light is the ease with which it can be controlled, but unless the switches are placed in their proper positions much of the convenience is lost. In ordinary rooms the sub-switches controlling the general lighting should be placed just inside the door, at about 4 feet from the floor. In all cases, however, due allowance should be made for the special uses to which the room is put, the arrangement of the lighting and the placing of the wires. Main switches must always be placed in an accessible position, as near as possible to the point of entry of the supply cables.

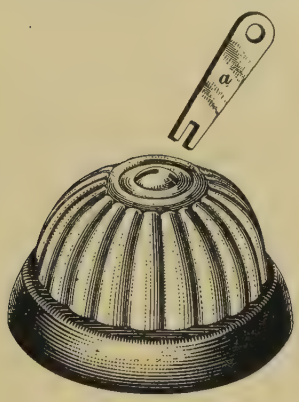


Fig. 15

Care should be taken that switches are not placed in positions where they are liable to accidental damage, and should be so fixed that gravity will tend to open rather than close them, that is, they should be placed with the handles up when closed.

FUSES

30. A **fuse,** or as it is sometimes called, a **cut-out,** is essentially a protective device, its purpose being to automatically open the circuit in which it is fixed when the current exceeds a certain predetermined value. Fuses usually consist of short lengths of soft metal or copper wires which melt when a current heavier than the normal passes through them.

The current at which fuses will melt or *blow* varies according to the material of which they are composed and according to their cross-sectional areas. Table II gives a list of the gauges of tin and copper wires with the current at which they *fuse*, or *blow*, according to tests made by Sir W. Preece. A soft metal fuse, of tin or lead, soldered to hard metal contacts is to be preferred to one composed entirely of hard metal, for the protection of sub-circuits, on account of the much greater ease with which it melts. For main fuses carrying a comparatively large current, copper wires are, however, to be preferred, as they do not oxidize or get brittle in use as readily as those of softer metals.

TABLE II

FUSING CURRENTS OF TIN AND COPPER WIRES

Current, in Amperes	Tin Wire Standard Wire Gauge	Copper Wire Standard Wire Gauge	Current, in Amperes	Tin Wire Standard Wire Gauge	Copper Wire Standard Wire Gauge
2	31	43	20	17	27
3	28	41	25	16	26
5	24	38	30	15	25
10	21	33	40	14	23
15	19	29	50	12	22

31. Requirements of a Fuse.—A fuse should fulfil the following conditions:

1. It must effectually interrupt the current when it exceeds the normal by 75 per cent.

2. Its terminals must be so spaced, or screened, that an arc cannot be maintained when the fuse is blown. The minimum distance between the terminals of fuses for use on circuits up to 250 volts should be $2\frac{1}{2}$ inches.

3. The cover must be so arranged that it will retain all melted metal, and both cover and base must be of rigid insulating and non-combustible material.

32. Types of Fuses.—The cut-out illustrated in Fig. 16 (*a*) and (*b*) is a good example of the china single-pole type. In Fig. 16 (*a*) is shown the cut-out with cover in place, and at (*b*) is shown the method of connecting the conductors. The conductor is cut as near to its point of connection as possible, and the ends inserted in the terminals *t* which are directly connected to the binding screws *s*, to which the fuse wire *a* is attached as shown. It will be noticed that the china block *b* is inserted between the terminals and prevents an arc from being maintained across them when the fuse is blown. Though this form of cut-out is satisfactory for small installations on perfectly dry premises, it has the following disadvantages :

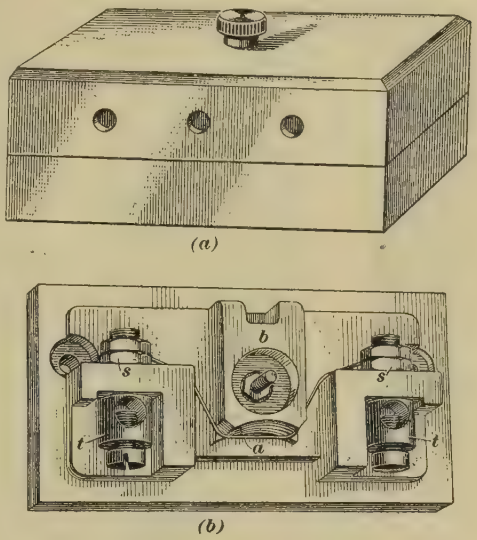


FIG. 16

1. The great heat generated during the blowing of the fuse may break the cover and allow the molten metal to escape.
2. The arc is not extinguished quickly enough.
3. The person replacing the fuse is liable to receive a shock.
4. Unless the cover is removed, it is impossible to tell whether or not the fuse is blown.

33. Enclosed Fuses.—Fuses of the **cartridge**, or **enclosed, type** overcome these disadvantages. The cut-out shown in Fig. 17 is known as the **Mordey** fuse. The fuse wire is soldered at each end to the metal contacts *c*, *c*, and is contained in the fibre tube *f*, which is partly filled with a specially prepared dust that extinguishes the arc immediately it is formed. The tube is

fitted with a white paper indicator *a* which blackens when the fuse is blown.

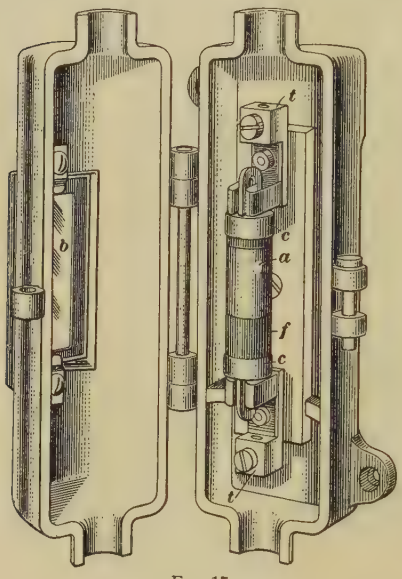


Fig. 17

The iron case shown in Fig. 17 is the type usually employed in damp situations, or where the fuse is liable to accidental damage. The glass window *b* enables a fuse to be inspected without opening the case. The ends of the conductor are inserted in the terminals *t*, *t*.

34. Distribution Boards. In practical installation work it is customary to split up the lights on a building into a number of sections, each section forming a separate circuit controlled by double-pole fuses. These fuses are always grouped at a convenient point and are enclosed together in a special case. The fuses and case make up a **distribution board.**

The rules of the Institution of Electrical Engineers require that: "Distribution boards must be placed in a dry position and be so arranged that a fire thereon cannot spread, whether occurring at the front or back. Their bases must be of incombustible and insulating material, with moisture-proof bushes fitted at the points of support, if the material is hygroscopic. The possibility of a permanent arc must be prevented, either by sufficient spacing of all live parts or by the use of separating partitions."

35. Types of Distribution Boards.—The cases of distribution boards are either of iron or of seasoned hardwood. The latter may safely be used in dry situations where there is no liability of accidental damage; ironclad boards should, however, be used in all damp or exposed positions. The case should be provided

with a glass front in order that the condition of the fuses can be seen without opening, and with a lock and key or other secure fastening.

Fig. 18 (*a*) shows a four-way distribution board in teak case. The base consists of two slabs of enamelled slate separated by an ebonite fillet *f*. The current-carrying parts are of copper, the current density not exceeding 800 amperes per square inch at the full rated load. The main conductors from the point of supply are sweated into two lugs at the back of the board, which are directly connected to the long copper bars *b*, *b*, known as **bus-bars.** The bus-bars distribute the current to the fuses,

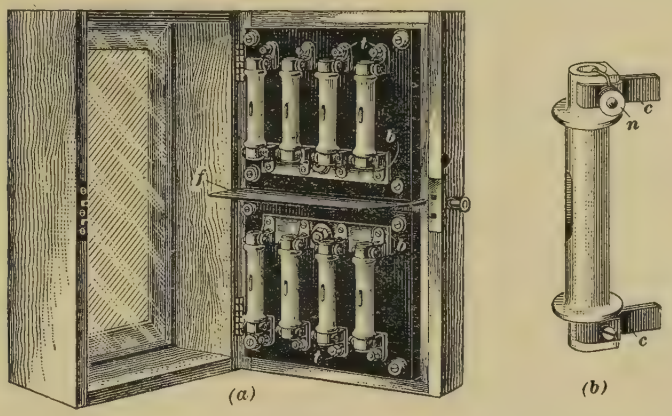


Fig. 18

whence it is taken by wires connected to the terminals *t*, at the top and bottom of the board, to the various sub-circuits.

At (*b*) is shown a more detailed view of the fuse holder, or *bridge*, as it is sometimes called. The fuse wire is attached at its ends to the terminals *n*, one of which is shown in view (*b*), and passes completely through the porcelain tube. The contacts *c*, *c* are pressed into clips attached to the bus-bars and terminals, and can be removed for the replacement of the fuse. Every board should be provided with at least one spare bridge wired ready for use.

36. Position of Fuses and Distribution Boards.—The rules of all supply and insurance companies require that a pair of single-pole

fuses shall be placed in an accessible position as near to the point of entry of the supply mains as possible. Fuses for sub-circuits must be grouped together in one or more convenient and accessible positions, isolated fuses being on no account permissible. The most convenient height for distribution boards is about 7 feet from the floor.

37. Mounting of Switches and Fuses.—Switches, fuses, and electrical apparatus generally, should never be mounted direct on a brick or stone wall, on account of the dampness due to condensation. They should be screwed to a recessed wooden block firmly fixed to hardwood plugs inserted in the wall. In damp places the wooden block, or *patera*, as it also is termed, should be mounted several inches away from the wall on wooden batten. Several inches of slack wire can be stowed away in the recess of the block, and it is worth while to see that this is done, as it saves joints in the event of a wire breaking in removing or refixing the switch.

ELECTRIC FITTINGS AND ACCESSORIES

38. Arrangement of Lights.—No general rule can be given to determine the amount of light required to effectively illuminate a certain area, as the candlepower necessarily varies greatly with the character of the room, the arrangement of the furniture, and the style of decoration.

Table III gives an approximate idea of the light, in candlepower per square foot of floor area, required to illuminate the various rooms named under average conditions.

EXAMPLE.—A reception room, the floor dimensions of which are 20 feet by 15 feet, is to be evenly and sufficiently illuminated. How many 16-candlepower lamps are required ?

SOLUTION.—The floor area in square feet is $20 \times 15 = 300$. Selecting from Table III, the value ·4 c.p. per sq. ft., the required number of 16-c.p. lamps is

$$\frac{\cdot 4 \times 300}{16} = 7{\cdot}5, \text{ or } 8. \quad \text{Ans.}$$

39. Electric Fittings, or Fixtures.—The portion of an installation to which the light is attached may be roughly described as the electric fittings, or fixtures. They are generally ornamental

and frequently elaborate in design, but as their arrangement and construction are fully treated of in the Section relating to *Lighting Fittings*, the descriptions given here will be confined to the simple fittings and accessories in general use.

TABLE III

LIGHT REQUIRED FOR THE GENERAL ILLUMINATION OF ROOMS

Class of Room	Candlepower Per Square Foot of Floor Area
Living and reception rooms . .	·3–·4
Bedrooms	·15
Passages and corridors	·12
General offices	·4–·5
Private offices	·2
Showrooms	·5
Public halls, etc.	·6
Factories	·15

40. Ceiling Rose. — A device, Fig. 19, called a **ceiling rose**, is employed to support the simpler forms of fitting and to connect them to the circuit. It is usually made of white china, with the exception of the current-carrying parts, which are of metal. The circuit conductors are brought through holes in the base to the terminals *t*, *t*, which are on the same plate as the screws *s*, *s*, under which the flexible wires from the lamp are attached. In order to take the weight of the fitting from the terminals, the flexible conductors are first passed through the holes *y*, *y*, shown in the separating bridge *b*.

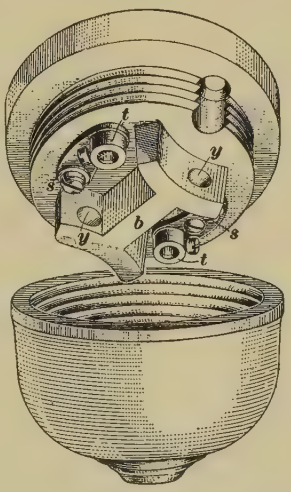


FIG. 19

41. Lampholders.—A lampholder should: (1) connect the lamp with the circuit conductor; (2) carry the lamp in such a way that it can be easily and quickly removed; and (3) provide good insulation.

42. Bayonet Holder.—The type of lampholder in most general use in Great Britain is shown in Fig. 20. The separate parts are shown in view (*a*) and the assembled parts in view (*b*). As it is used with lamps provided with b.c. caps, it is known as the **bayonet, or b.c., holder.** The conductors from the circuit are brought through the brass cover *c* to the terminals *t* of the china interior *d*. These terminals are connected to the spring

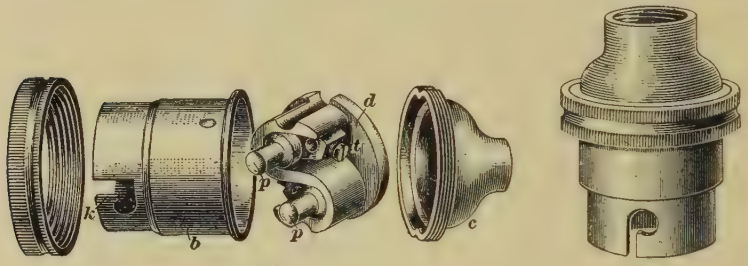


FIG. 20

plungers *p*. The mouth of the body *b* is of slightly larger diameter than the cap of a lamp, so that the two pins which project from the sides of the cap engage with the recess at the bottom of the grooves *k* and are held there by the pressure of the spring plungers, which also make connection with the contacts at the bottom of the lamp. This lampholder is intended to be screwed on to the arm of a fitting, and as it has no attachment for carrying a shade, is known as a plain bayonet holder.

43. Cord Grip.—Lampholders are often fixed directly to a flexible cord, in which case they are fitted with a device, called a **cord grip,** for taking the weight of the lamp and shade away from the small terminals of the holder. Fig. 21 shows a cord-grip holder which is also fitted with an additional ring *s* to carry a shade. The shade is made with a hole of diameter a little larger

than that of the body of the holder, and is firmly held between the two rings *r* and *s*. The cord grip is shown at *g*, and consists of two pieces of shaped wood through which the two flexible cords pass. The cap *c* is then screwed tightly in position, and from its conical shape presses the two pieces of wood together, which in turn grip the cords and hold them fast, so that the weight of the fitting is taken on the cords at this point rather than at the terminal connections lower down.

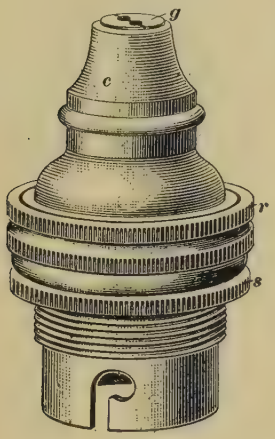


Fig. 21

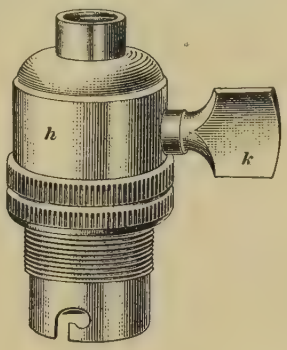


Fig. 22

Under some circumstances it is desired that the light shall be controlled at the lamp itself, in which case a **key-holder,** which combines the functions of a switch and lampholder, is employed. A type of this holder is shown in Fig. 22, where *h* is the holder, similar in all respects to that described in Figs. 20 and 21, with the addition of a key *k* which acts on a switch inside the holder and makes or breaks the contact at will.

44. Wall Plugs.—Special connectors, known as **wall plugs,** are principally used in conjunction with portable standards and hand lamps, by the use of which a fitting can be easily and quickly detached from a circuit. The form of plug generally in use in Great Britain is known as the **two-pin plug,** and its construction is illustrated in Fig. 23 (*a*) and (*b*). The removable portion *a* is the plug proper, while the body *b*, into which it fits, is known as the **socket.** The circuit wires are connected in the usual manner to the terminals *t*, *t*, Fig. 23 (*a*), which are mounted

on the same metal plate as the hollow screws *s*, *s*, which serve to hold the china cover *c* on to the body *b*. The flexible wire from

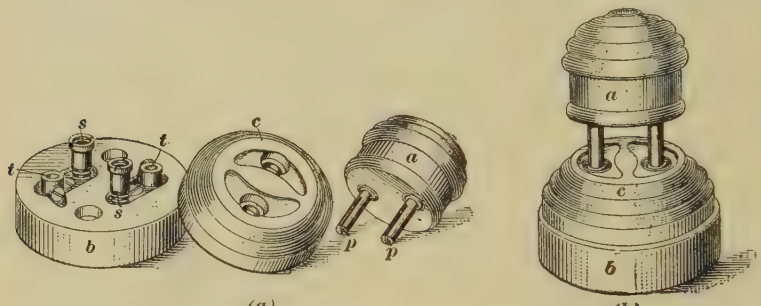


Fig. 23

the portable fitting is connected to terminals under the cover of the plug *a*, and these are in turn directly connected to the

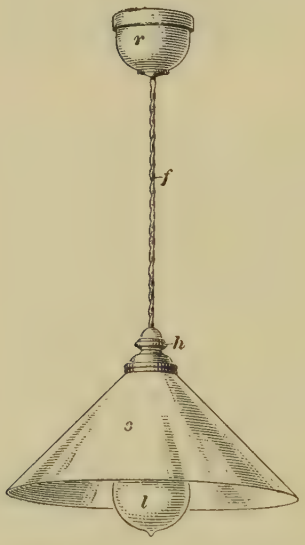


Fig. 24

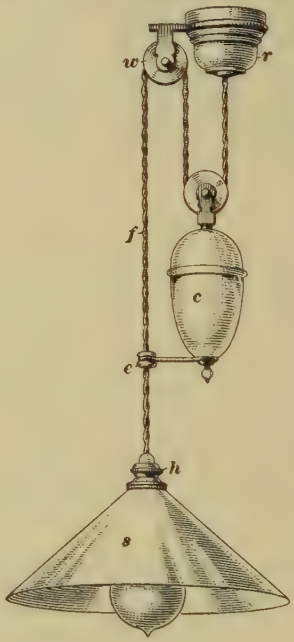


Fig. 25

split pins *p*. These pins are made to fit into the hollow screws *s*, thus completing the circuit. The plug illustrated is, with the

exception of the current-carrying parts, made of china; hardwood or fibre covers are, however, permissible.

The wall plugs throughout an installation should be controlled by separate switches in each room and should all be of the same type, in order that the portable fittings may be interchangeable.

45. Pendants.—The fitting illustrated in Fig. 24 is known as a **plain pendant**, and is not only the cheapest, but also one of the most efficient fittings used. It consists simply of the ceiling rose *r*, the flexible wire *f*, the holder *h*, and the lamp *l*, together with the white opal shade *s*. This shade, usually 10 inches in diameter, serves to reflect the light downwards and gives a finished appearance to the fitting.

Fig. 25 shows a *plain counterweight pendant* which allows of an adjustment in the height of the lamp. It comprises a plain pendant with the addition of the counterweight *c* and the pulley-wheel *w*, with a greater length of flexible wire connected to the ceiling rose *r* and holder *h*. When the lamp is raised or lowered, the wire passes through the eye *e*, supported by the counterweight, and prevents the latter from turning.

46. Ceiling Fittings.—Where there is not sufficient headroom for a pendant, ceiling fittings are used for general lighting. A plain 3-light ceiling fitting is shown in Fig. 26, made up of a *ball body a*, a *back plate b* and three shade-carrier holders *c*, *c*, *c*. A similar ball body to that illustrated, but arranged for insertion in an ordinary lampholder, is used where two low-voltage metallic-filament lamps in series replace an ordinary high-voltage carbon-filament lamp.

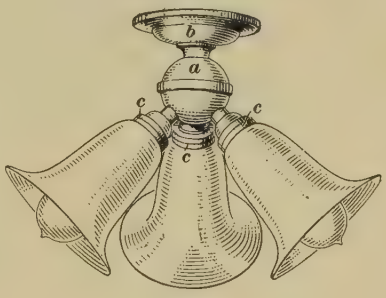


FIG. 26

47. Brackets.—A **bracket** is used in cases where a centre fitting would be either unnecessary or unsightly, and in large rooms in which the centre fittings do not sufficiently illuminate

the sides of the room. Fig. 27 shows a simple ornamental wall bracket, in which the height of the lamp can be adjusted by shortening or lengthening the flexible cord *f*. It is advisable that the joint between the flexible cord and the fixed wires, which bring current to the bracket, be made by brass terminals on a porcelain base. Ordinary soldered and insulated joints are liable to be damaged when fitting them into the space behind the back plate.

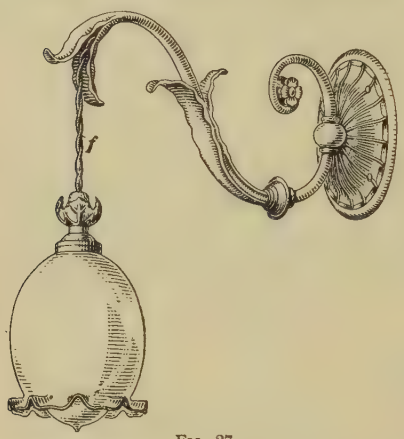


FIG. 27

48. Portable Fittings.—In cases where it is desirable to vary the position of a light, **portable fittings** are employed in conjunction with wall plugs or ceiling fittings. Fig. 28 shows a **table**

FIG. 28

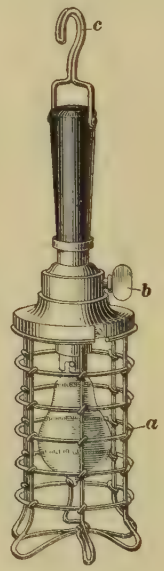


FIG. 29

standard for use on a small table or piano, and Fig. 29 a hand lamp for wine cellars, motor garages, and similar premises. This lamp is protected by the wire cage *a*, so as to prevent its being damaged by knocking against a wall or partition. It is provided with a key switch *b*, and has a hook *c*, by which it may be hung when not in use.

49. Height of Fittings.—Pendants or electroliers are the most suitable fittings for general lighting, and the height of the lamps should be just sufficient for the even illumination of the whole room. If too high, light is wasted and the general effect diminished; while, if too low, the floor directly below the fitting will be brilliantly illuminated, while the surrounding portion will be in comparative darkness.

For corridor lighting, a good general height is 8 feet from the floor to the lamp; but the arrangement of the fittings in the other parts of the premises will depend almost entirely on local conditions. Brackets should usually be fixed about 5 feet 6 inches from the floor, but these, too, must be varied to suit the individual circumstances. Wall plugs are, as a rule, fixed on the skirting boards. This position is a good one if the fitting is not frequently moved and a controlling switch is placed immediately above the plug, so that the light can be switched on or off by the foot. If the fitting is frequently disconnected from the plug, the necessary bending of the body is unpleasant, and in such cases the plug should, if possible, be fixed at a height of about 3 feet from the floor.

ARRANGEMENT OF CIRCUITS

SYSTEMS OF DISTRIBUTION

50. Two-Wire System.—The simplest method of distribution for both direct and *single-phase* alternating currents is known as the **two-wire system,** to which in modern interior wiring all other methods are reduced. The general arrangement of the connections is shown diagrammatically in Fig. 30, it being assumed that

the current enters through the conductor a, passes through the blade c, when the latter is closed, into the wire a', then through

Fig. 30

the lamps d into the return wire b', and through the other blade c' into the wire b.

51. Electric supply companies, when bringing their mains into a consumer's premises, usually finish off the end of each cable with a single-pole fuse, which serves the double purpose of protecting their mains in the event of a short circuit on the installation and providing a terminal to which the interior wiring is connected. Most supply companies require, further, that the consumer shall provide a double-pole switch and a pair of single-pole fuses, which must be fixed as near as possible to the point of entry.

52. Three-Wire System.—Supply companies adopt the **three-wire system** on account of the great saving of copper in the mains effected by its use. Fig. 31 shows the general arrangement

Fig. 31

of such a system. Three conductors a, b, and c are brought into the building, the pressure between them being so arranged that the voltage between the positive a and negative conductors c is twice that between the third conductor b, which is called the **neutral wire,** and either the positive or the negative wire. The positive and negative conductors of a three-wire system are known as the *outers*, while the neutral and positive, or neutral and negative, form the *inners*. The main fuses are here placed outside of the main switches, but it is preferred by some to have them on the house side, that is, between the lamps and the main switches, as in Fig. 30.

The pressure between the outers of a three-wire system is usually in the neighbourhood of 400 volts, and therefore unsuitable for incandescent lighting work, for which the pressure must not exceed 250 volts. The outers are therefore usually reserved for the connection of motors, while lamps are connected across the inner wires in two entirely distinct installations, separated at all points by a distance of at least 6 feet.

53. Five-Wire System.—An extension of the three-wire system, by which four different pressures can be obtained, is known as the **five-wire system.** When lights are taken off the lowest voltages, four distinct installations are required. The precautions as to keeping the several installations apart must be even more strict than in the case of the three-wire system. In both three-wire and five-wire systems care should be taken that the load on the sections is as nearly equal as possible.

54. Alternating-Current Systems.—Alternating currents differ from direct in that the latter flow continually in one direction, while the former changes its direction at regular intervals of time, the current gradually attaining the same strength in each direction. The changes in direction are regular, and take place at from fifty to one hundred times per second; each complete reversal from one positive maximum value to the next positive maximum value is known as a **period** or **cycle.** The number of cycles occurring per second is known as the **periodicity,** or **frequency.** If two alternating currents of the same frequency arrive at similar points in their cycles, the maximum or the zero points, for instance, at the same instant, the two currents are said to be **in phase;** while, if they do not arrive at similar points in their cycles at the same time, they are said to **differ in phase.**

55. Single-Phase Systems.—If an **alternator,** or machine, delivering an alternating current, has a single winding and furnishes only one current, it is called a *single-phase alternator*, and its current a **single-phase current.** The magnetic properties of alternating currents vary in many important particulars from those of direct currents; but for wiring work the calculations

remain the same, and a lamp which takes ·3-ampere current for 16 candlepower on a direct-current circuit will still require ·3 ampere on an alternating supply.

One precaution rendered necessary by the peculiar magnetic properties of alternating currents must, however, be observed, and this is, that in all cases in which cables delivering an alternating current are protected by metal tubes, the lead and return wires must be enclosed in the same tube. The connections for a single-phase system are exactly similar to those described in Art. 50 for two-wire direct currents.

56. Two- and Three-Phase Systems.—For certain applications, alternators are provided with several windings, so arranged that each gives an alternating current differing in phase from the others; such a machine is called in general a *polyphase alternator*. Those in general use have either two or three separate windings, and are called **two-phase** or **three-phase alternators**, as the case may be. Two- and three-phase currents are rarely brought into a consumer's premises for lighting purposes, the usual practice being to tap one phase only, in which case the system will be simple single-phase.

57. Transformers.—A **static transformer** is a device which can only be employed on alternating-current circuits for changing a current of one pressure to another of a higher or a lower pressure. It consists essentially of an iron core on which are placed two coils of wire, a primary coil and a secondary coil. The core is made up of thin iron plates, or laminations of proper shape, punched from large sheets and built up into proper thickness by using a number of laminations and bolting of clamping them together. Fig. 32 shows a common type of transformer; C is the core and P, S, S_1, P_1 are the coils, each wrapped with insulating material.

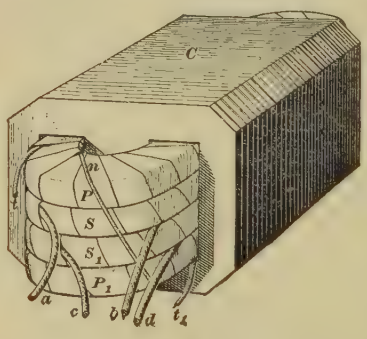


FIG. 32

The *primary coil* is that into which the current to be transformed is led; the *secondary coil* is that from which the transformed current is taken. In Fig. 32, the primary and the secondary coils are each made in two parts; the halves of the primary P and P_1 are placed outside of the halves of the secondary S and S_1.

Each half coil has two terminals, or leads, a–b, c–d, t–n, and n–t_1, the halves of the primary coil being connected in series by the common terminal n. The secondary leads a–b and c–d are brought out separately, so that they may be connected in series or in parallel, as desired.

58. The **transformation** is in proportion to the relative number of complete turns, or convolutions, of wire in the primary coil and in the secondary coil. For example, if the primary coil is made up of 100 turns and the secondary coil of 10 turns, the ratio of transformation will be 100 to 10, or 10 to 1; and if an alternating current were led into the primary coil at a pressure of 1,100 volts, another alternating current very nearly ten times as large could be taken from the secondary end at 110 volts. Such a device permits the transmission of electric energy at a high pressure and of a low current strength, with correspondingly low losses, from the power station, where the engines, dynamos, etc., are located, to the buildings, possibly miles away, where the energy is to be used. Near the place where the energy is to be used, transformers may be connected so that the pressure will be reduced and the current increased.

59. Transformers for Metallic-Filament Lamps.—The electric currents delivered by the supply companies have rarely pressures less than 100 volts, and are more usually of 200 to 250 volts, on account of the excessive expenditure on copper which would be required for mains with low voltage and heavy current.

Metallic-filament lamps for voltages above 100 are not only exceedingly fragile, but are unobtainable for less than 16 candlepower, a unit of illumination which is too great for many situations. The 25- and 50-volt lamps are, however, much stronger, have a longer life, and can be obtained to give a light of 8 and 12 candlepower.

In order to take advantage of the great saving in energy consumption which is to be effected by the general adoption of these low-voltage lamps, a special type of transformer, called **auto-transformer,** in which the secondary is simply a tapping from the primary winding, is now extensively employed on alternating-current circuits to reduce the supply pressure to 25 or 50 volts. A form of this transformer, in which the terminal *p s* is common to both primary *p* and secondary *s*, is illustrated in Fig. 33. A diagram of the connections is given in Fig. 34.

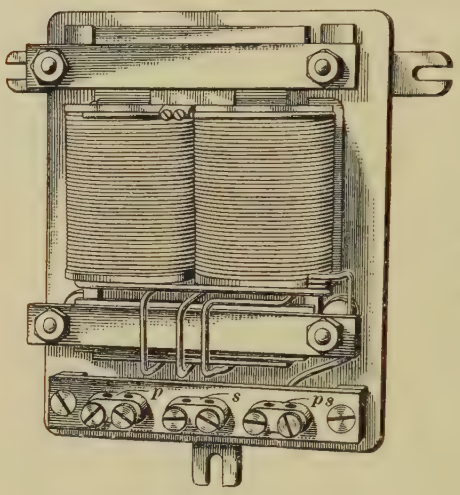


FIG. 33

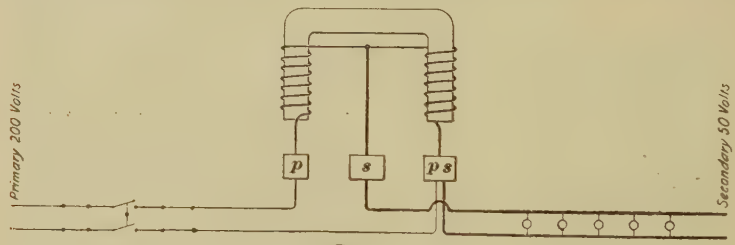


FIG. 34

60. In calculating the sizes of the conductors to be used in connection with a small transformer, it should be remembered that the lamps will not be supplied at the supply company's voltage of 200, but at the secondary pressure of the transformer, or 50 volts, as shown in Fig. 34, and the current required will therefore be increased.

The pressure drop on a given conductor is directly proportional to the current conveyed and will be exactly the same whether the lamp voltage is 25 or 250, as long as the current is the same

in each case. It will therefore be seen that in the case of a low-voltage installation the permissible drop must be very much reduced, for while a drop of 3 volts on a 250-volt installation would be comparatively negligible, amounting to only 1·2 per cent., the same drop on a 25-volt installation would appreciably affect the light of the lamp, as it here would amount to 12 per cent.

INTERIOR WIRING SYSTEMS

61. The Looping-In System.—The method adopted in modern wiring work, to avoid the necessity of joining the conductors at the various lamps and switches, is known as the **looping-in system.** Fig. 35 shows this system applied to a circuit consisting

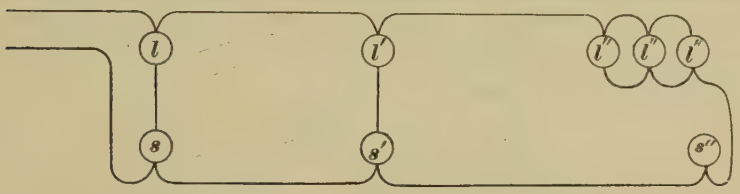


FIG. 35

of two single lights l and l', each on one switch s and s', and a group of three lights l'' l'' l'' on one switch s''. Instead of joining short lengths of conductor to the circuit wires for each lamp and switch, the circuit conductors are themselves run to each lamp and switch and connection is made by baring and inserting them in the terminals.

It is customary to employ short lengths of wire between the various terminals, but, if possible, it is preferable to adopt the method shown in Fig. 36, which retains the continuity of the conductor. Fig. 36 (*a*) shows the wire with the insulation removed at the place to which connection is to be made. In (*b*), the bared part is bent double ready for insertion in a terminal.

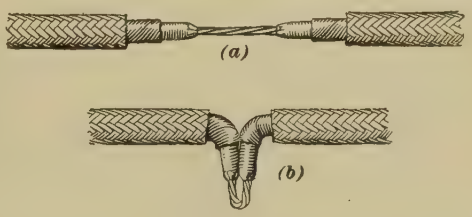


FIG. 36

62. The Distribution-Board System. — All modern installations are divided up into a number of circuits, usually of from 6 to 10 lights each, so arranged that, as far as possible, no part of the premises shall be left in entire darkness in case a circuit fuse should blow. Each circuit is protected by a double-pole fuse in a distribution board fixed in a convenient central position.

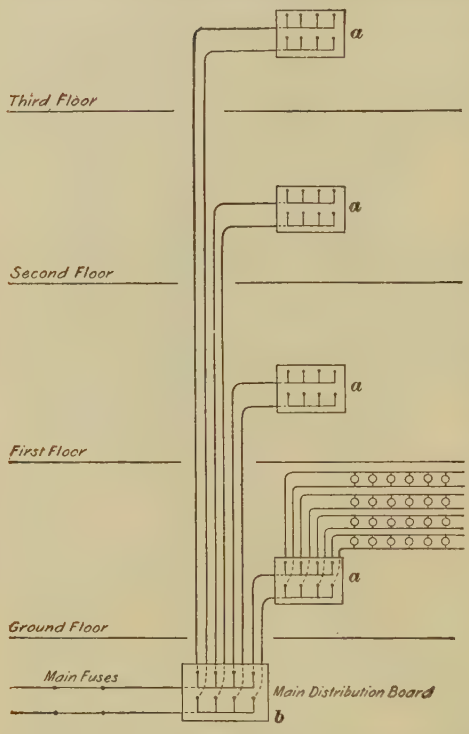


Fig. 37

In large installations this system is extended by placing one or more distribution boards *a*, Fig. 37, on each floor, controlled in turn by fuses in a main distribution board *b* placed near the point of entry. The distribution board *a* on the ground floor is shown connected to four lamp circuits.

— — —

ERECTION OF CONDUCTORS

63. The recognized systems for the erection and protection of electric cables for interior wiring may be broadly divided into two classes: the *open* and the *enclosed*, or *concealed*, systems.

64. The Open System.—The oldest method of wiring, known as the **open system,** is one in which the wires are merely suspended at intervals and are not protected from mechanical injury. It has little to recommend it, except its cheapness, and

has been almost entirely superseded in Great Britain by the enclosed system, in which the wires are protected by either wooden casings or steel tubes. In the open system the conductors are supported by porcelain or wooden cleats, fixed in such a manner as to secure the permanent spacing of the conductors from the walls, ceilings, and all structural metal work and pipe work by at least $\frac{1}{2}$ inch. The rules of the Institution of Electrical Engineers permit the bunching, that is, running together, of wires carrying less than 5 amperes; but unless the flexible system, subsequently described, is being employed, it is usual to separate wires of opposite polarity by at least $2\frac{1}{2}$ inches.

65. Open-System Fittings.—Figs. 38 to 44, inclusive, show a few of the many varieties of porcelain fittings suitable for installing exposed, or open, wiring. They are made in various sizes, to suit different conditions. Fig. 38 shows a section of a

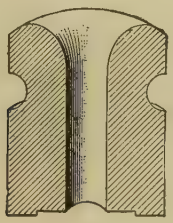


FIG. 38

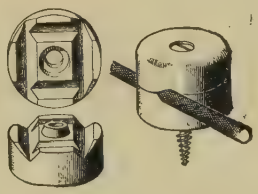


FIG. 39

porcelain knob, which may be attached to the wall or ceiling by a screw through the centre hole. The wire is fastened in the groove on one side by a piece of wire, called a

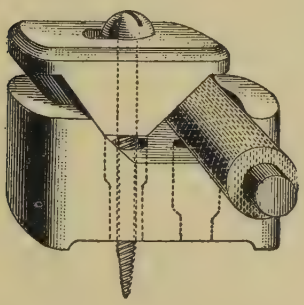


FIG. 40

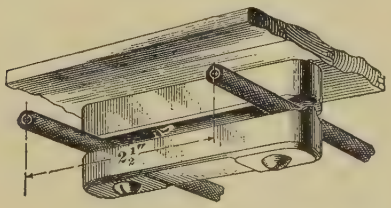


FIG. 41

tie-wire, the insulation of which must be as good as that of the

wire being tied. Fig. 39 shows a **knob cleat** that gives a neater appearance than the knob with tie-wires. Fig. 40 shows another form of single-wire cleat more used for larger size wires. Fig. 41 shows a two-wire cleat designed to separate the wires $2\frac{1}{2}$ inches. Similar cleats are made for three wires. It is always best to use screws in putting up knobs and cleats. In many installations, wired on this system, the wires must be kept at a minimum distance of 4 inches from one another.

Figs. 42 and 43 show each a porcelain **tube,** or **bushing,** for insulating holes through joists and for separating wires at crossings. Fig. 44 shows a longer tube, to be used through floors or partitions ; the shoulder *a* leaves enough of the end of the tube projecting from the wall or floor, so that the wire may be well protected.

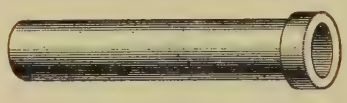


Fig. 42

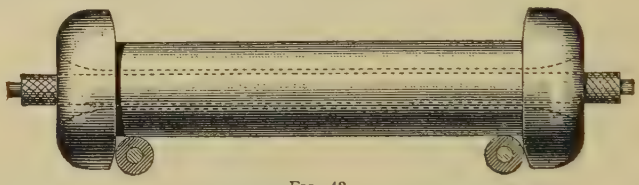


Fig. 43

66. Flexible Wiring System. — A variation of the ordinary open system, in which ordinary flexible wire is employed, is now largely used in wiring small houses in Germany, and efforts are being made to introduce it into Great Britain on account of the low cost of erection. In this system, known as the **flexible system,** ordinary twin flexible wire, on insulators similar to that illustrated in Fig. 39, is run from the distribution board to the various lights and switches. The methods of crossing circuits and passing through walls and floors is very similar to those just described, except that in this case both conductors are necessarily enclosed in the same tube. All joints between wires run on this system must be made on porcelain bases. Ordinary soldered and insulated joints cannot be permitted.

67. Enclosed, or Concealed, System.—The most satisfactory method of wiring a building is the **enclosed,** or **concealed, system,**

in which the wires are enclosed throughout their length in a wooden or metal casing.

Fig. 44

Enclosed systems may be broadly divided into two classes: the **wood-casing system,** in which the conductors are enclosed throughout their length in moulded strips of wood, and the **conduit system,** in which the wires are protected by a continuous system of steel or iron tubes. In modern wiring work the enclosed system has almost entirely superseded the open, on account of the better support and protection of the wires.

68. Wood-Casing System.—Casing for electrical purposes is usually made of American whitewood, a wood which can be obtained in the required lengths and is singularly free from knots. It is usually supplied in lengths of about 12 feet, and can be obtained in various sizes, from $1\frac{1}{2}$ inches wide by $\frac{1}{2}$ inch deep to 6 inches wide by $1\frac{1}{2}$ inches

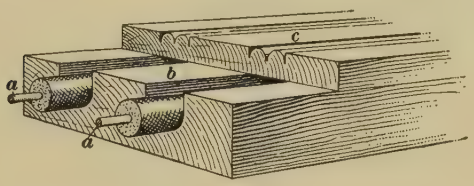


Fig. 45

deep. The wires *a*, *a* are carried in two **U**-shaped grooves, as shown in Fig. 45, separated by a fillet *b* varying from $\frac{1}{2}$ inch in width in the smaller sizes to 1 inch in the larger. They are protected by a thinner strip of wood *c* which is screwed on to the casing, and known as **capping.**

The use of casing is now almost entirely confined to installations upon old buildings, where it is undesirable to chase the walls for the insertion of *conduit.* It must not be used in any places where there is the least dampness. For surface work casing is far more sightly than tube work, and, by

panelling out the ceilings and painting to match the existing decoration, it can be made practically unnoticeable.

69. Erection of Casing.—Before erection, both casing and capping should be well painted inside and out with two coats of either a good oil paint or orange shellac varnish. In the smaller sizes casing is fixed by a screw through the centre fillet to a hard-wood plug previously inserted in the wall; the larger sizes require two screws in the outer fillets. Round-headed brass screws in pairs in the outer fillets of the casing should be used for fixing capping.

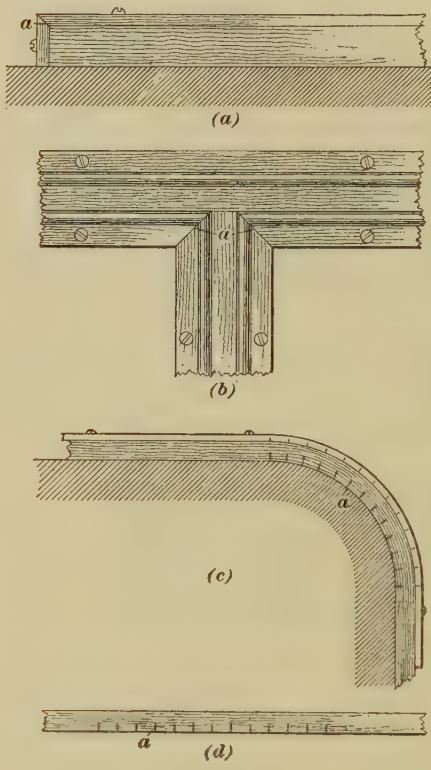


FIG. 46

Fig. 46 (*a*) shows the usual method of finishing off the end of the casing by forming a stopped end as at *a*, by cutting and mitring the capping. The proper method of making a **T** joint using a birdsmouth joint is shown at *a*, in view (*b*). A neat method of rounding a corner by *kerfing* is shown at *a* in view (*c*). In *kerfing* a number of shallow saw cuts is made in the under side of the casing, as indicated at *a* in view (*d*), which represents the capping or casing before bending.

Fig. 47 shows the proper method of separating the conductors by a *bridge* in a vertical and horizontal crossing. At *a* in view (*a*) is shown the casing as fixed to the wall face and running in a

horizontal direction, at *b* is shown the casing which, running in a vertical direction, has to cross the casing *a*; it is therefore carried over or bridged across the casing *a*, as shown at *c*. The separate ends of the casing *b* abut against the casing *a* at the points *d* and *e*, as shown in the side view (*b*) of casing *b*. A bridge piece *c* is laid over casing *a*, by means of which the wires are carried across *a*. Fig. 48 is an example of the manner in which a **T** joint should be made to a switch or light when one conductor has to be taken from each groove of the casing. It will be seen from the sectional view at (*a*) that a short length of casing *d* is let into the wall and that the wire *e* from the top groove of casing *a* passes through this, under the wire *c* in the lower groove, and is separated from it by the bottom of the main casing *b*. An outside view of the joint is shown in (*b*), where the piece *d* is indicated by dotted lines.

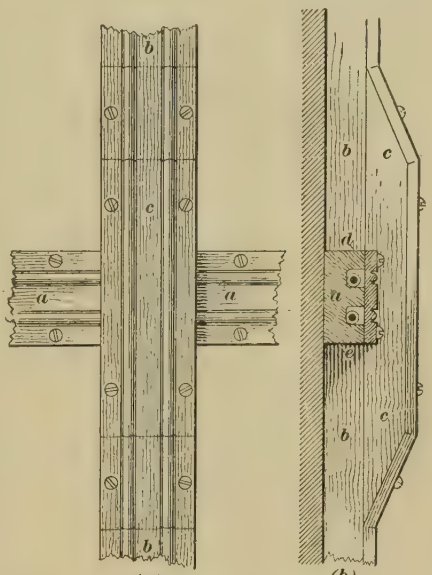


FIG. 47

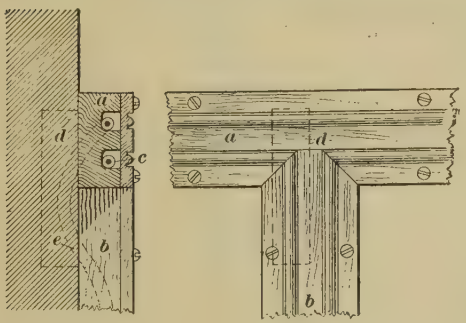


FIG. 48

70. The Conduit System. — The conduit system was introduced some years after the casing system, and, though it did not

at first find favour with engineers, it has now almost entirely superseded all other systems. The **conduit** consists of steel or iron tubes, the various lengths being coupled together by a variety of fittings by means of which bends, **T** joints, and junctions can easily be made. The great advantages of the system are that it affords an excellent protection to the conductors from mechanical injury, it can be made absolutely water-tight, and it supplies a sheathing for the conductors which can be made electrically continuous, which, if properly connected to earth, will directly carry away any leakage from the wires and reduce to a minimum any danger of shock to persons touching the system. The rules of the Institution of Electrical Engineers in regard to conduits require that all tube systems shall be continuous throughout and be connected to earth. Conduits are made commercially in three varieties: *Close joint, brazed* and *welded joint*, and *solid drawn*, or, *seamless;* the last two may be classed together as *screwed-tube conduits*. A large variety of fittings is also made for bends, **T**'s, and for the connection of switches and pendants to the conduits.

71. Close-Joint Tube. — The **close-joint tube** consists of a strip of iron rolled so as to form a tube, the edges being butted tightly together but not mechanically joined, and covered with a black insulating enamel. The various lengths of tube and fittings were originally joined together by merely slipping the tubes *a* into a socket *b*, as shown in Fig. 49, electrical continuity being supposed to be obtained by scraping away the enamel at the junction. The connection thus obtained is, however, a poor one, and two improved methods have since been introduced. In the first, shown in Fig. 50 (*a*), a steel pin *c* is driven tightly between the tube *a* and the fitting *b* into a groove *d* specially formed for it as shown at (*b*), and as the enamel is removed in inserting the pin a fair connection results. Fig. 50 (*a*) shows the complete joint, partly broken away to show the pin *c* in position.

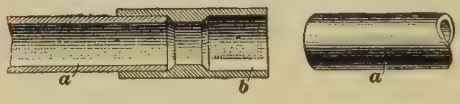


FIG. 49

The second method, illustrated in Fig. 51, makes use of a threaded, split cone nipple *c*, which grips the tube *a* securely when it is screwed into the fitting *b*. This method probably gives as good an electrical and mechanical connection as is likely to be obtained with light gauge plain tubes. On account of its liability to rust, close-joint tubes should only be employed in dry situations, and must not on any account be buried in plaster.

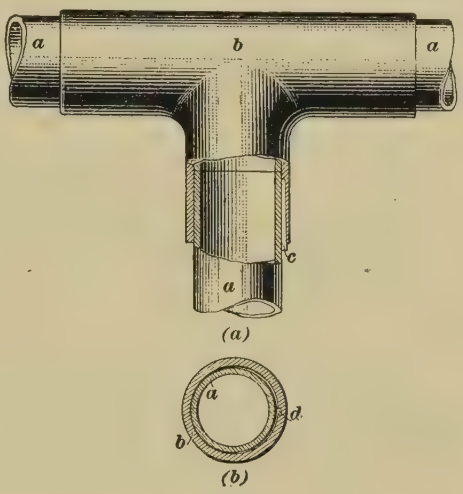


Fig. 50

72. Screwed-Tube System. — At present the **screwed-tube system** is the best for the protection of electric conductors, and as the lengths of tube and the fittings are screwed together at the joints after the manner of iron water pipes, the continuity of the system is electrically and mechanically as nearly perfect as possible, while the installation can be easily rendered water-tight. Solid-drawn tubes are to be preferred to either brazed or welded ones, on account of the absence of joints or seams.

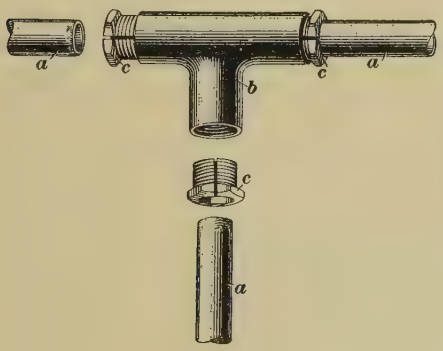


Fig. 51

73. Conduit Fittings.—Conduit fittings can now be obtained to answer almost every requirement, and a few of those most

generally used are illustrated in Fig. 52. At (*a*) is shown a *coupling*, or *socket*, used to connect two lengths of tube ; (*b*) is a *normal bend*, and (*c*) a plain **T**. It is customary to erect a conduit system complete before any wires are drawn in ; hence, boxes and inspection fittings similar to those illustrated at (*d*), (*e*), and (*f*) are inserted in the system, where necessary, to enable

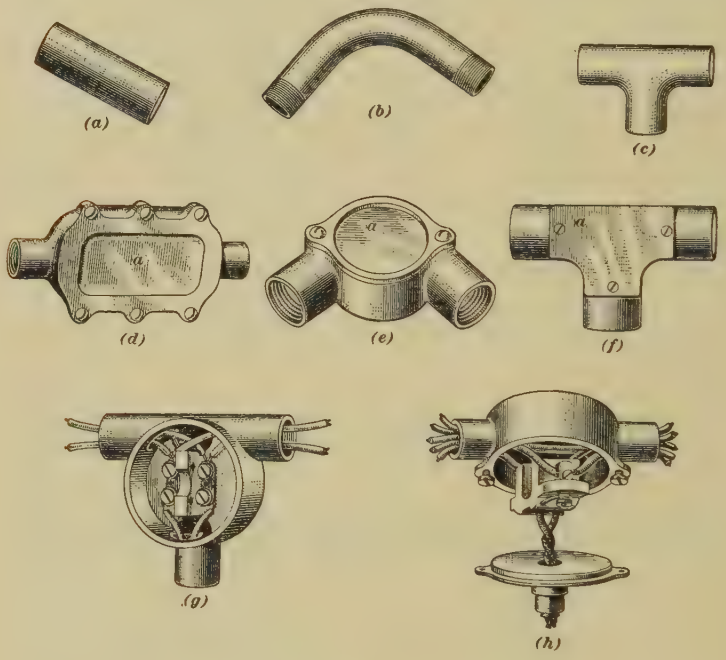


Fig. 52

the wires to be drawn round the bends. In each of these cases the cap *a* of the fitting can be removed so that ready access can be obtained to the wires inside for the purpose of drawing them in or out of the conduits or for inserting new ones. At (*g*) is shown a **T** with porcelain interior for looping to a branch light, and at (*h*) a ceiling rose box.

74. Erection of Conduit.—In rooms where conduit upon the surface would be unsightly, the tubes are chased into the walls

and covered with plaster; the screwed conduit system is the only one which can be satisfactorily employed under these circumstances. Conduits are fixed to the wall or ceiling by one of the devices illustrated in Fig. 53, the most satisfactory being the *saddle a*, which is fastened with brass screws to hardwood plugs inserted in the wall; *c* is known as a *clip*, and is similar to a saddle except that it is attached at only one end. The *crampet b* is sometimes useful in fixing tubing to brick walls. In damp situations galvanized tube should be employed instead of the enamelled.

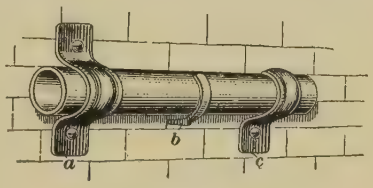


FIG. 53

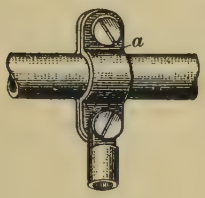


FIG. 54

75. The *earthing* of conduits is most important, and is usually carried out by connecting an insulated wire of not less than No. 14 S.W.G. to an iron water main. The wire is attached to the conduit by means of a clip similar to that shown at *a* in Fig. 54, the enamel being well scraped from the conduit beneath the clip. Every length of conduit in an installation must be efficiently connected to the others, and the system should be thoroughly earthed at least at three points. The ends of all tubes should be well reamed to remove sharp edges, and all outlets fitted with wood or ebonite bushes similar to that illustrated at *a* in Fig. 55.

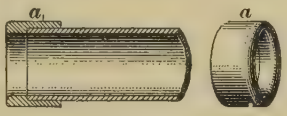


FIG. 55

76. Testing the Installation.—In addition to careful supervision, the wiring should be frequently tested both before and after completion. Breaks in continuity and short circuits are easily discovered by means of an ordinary bell and battery, but the most important test for insulation resistance requires a special instrument known as an *ohmmeter*. One type of this instrument is illustrated in Fig 56. It consists essentially of a small box *a* containing a generator, operated by means of the crank *d*, giving an E.M.F. of 500 volts. Connected to the

generator is an instrument which directly records the resistance in megohms of the circuit by means of a pointer *b* on a scale.

All switches of the installation having been turned on, one terminal *c* of the machine is connected to earth by means of a clean water pipe; the other terminal *c* is connected to one of the main cables. When the handle *d* is turned at the correct speed, the pointer *b* will indicate the insulation resistance of the installation to earth. When the instrument is not in use the handle *d* may be folded away in a recess and dial *b* protected by the cover *e*. The free end of the strap *f*, which is permanently fastened to the box at one end, hooks into the catch *g* and the box may thus be carried about with comparative ease.

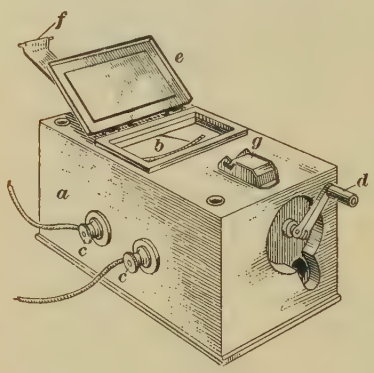
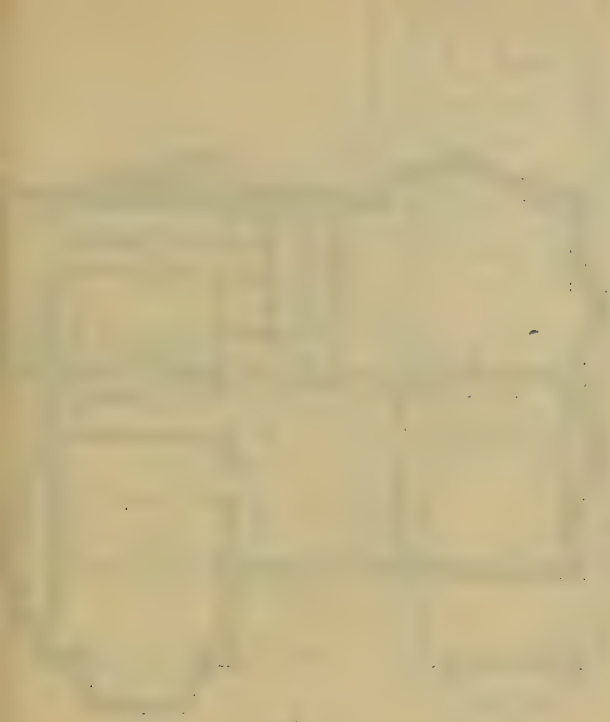
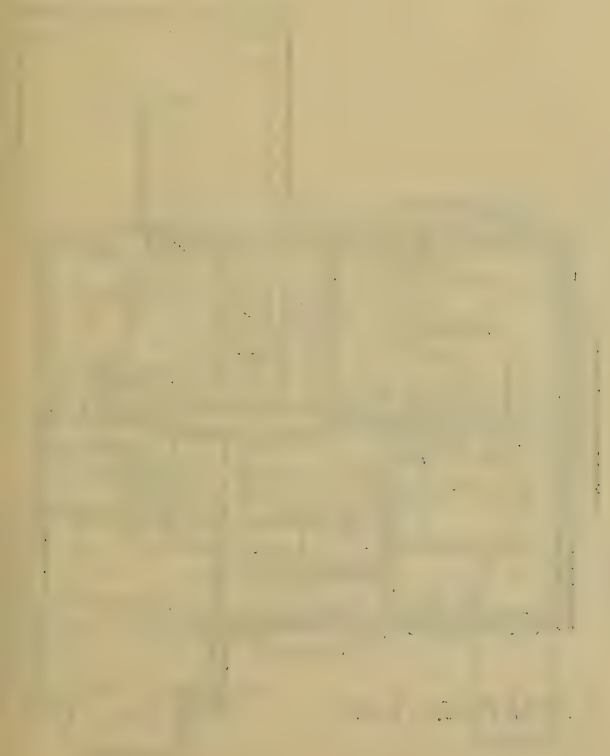


FIG. 56

77. The insulation resistance in megohms of an installation should not be less than 30 divided by the number of points under test. By *point* is meant the position at which a fitting is to be fixed, irrespective of the number of lights on the fitting. For instance, an installation of 50 points should have a minimum insulation resistance of $\frac{30}{50} = \cdot 6$ megohm. It must be borne in mind, however, that a good test does not necessarily imply a good installation, for the worst material may test well for some time after it is fixed. On the other hand, a really good installation on damp premises may give a poor test. It is of the utmost importance, therefore, that both workmanship and material should be subjected to the closest inspection during the whole progress of the work.

At a speed of 100 revolutions a minute of the handle *d*, the generator gives about 500 volts. Instruments for special purposes may be made to give 1,000 volts.





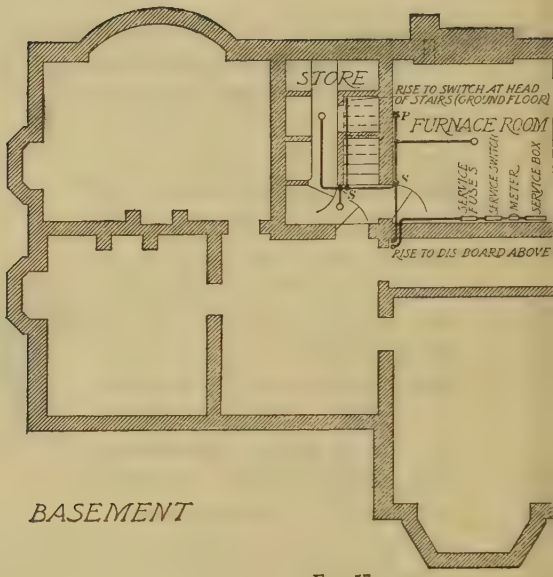

STORE
RISE TO SWITCH AT HEAD OF STAIRS (GROUND FLOOR)
FURNACE ROOM
SERVICE FUSES
SERVICE SWITCH
METER
SERVICE BOX
RISE TO DIS BOARD ABOVE
BASEMENT

Fig. 57

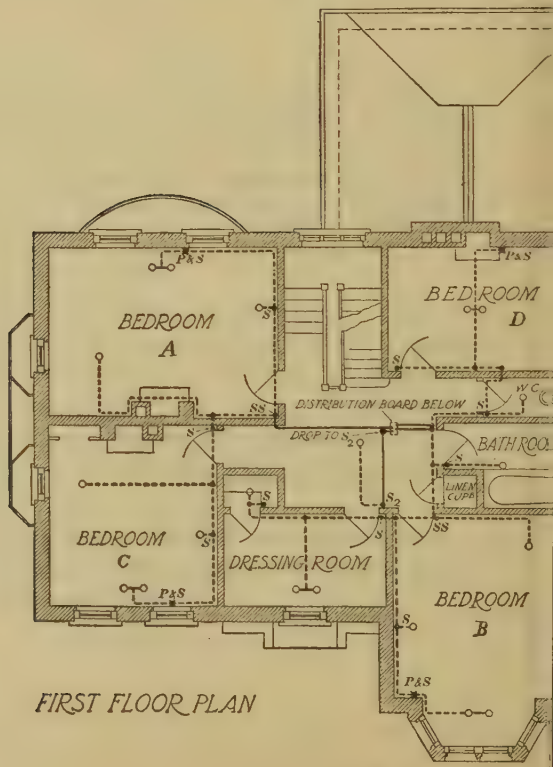

BEDROOM A
BEDROOM D
DISTRIBUTION BOARD BELOW
DROP TO S2
BATH ROO
LINEN CUPB
BEDROOM C
DRESSING ROOM
BEDROOM B
P&S
FIRST FLOOR PLAN

Fig. 59

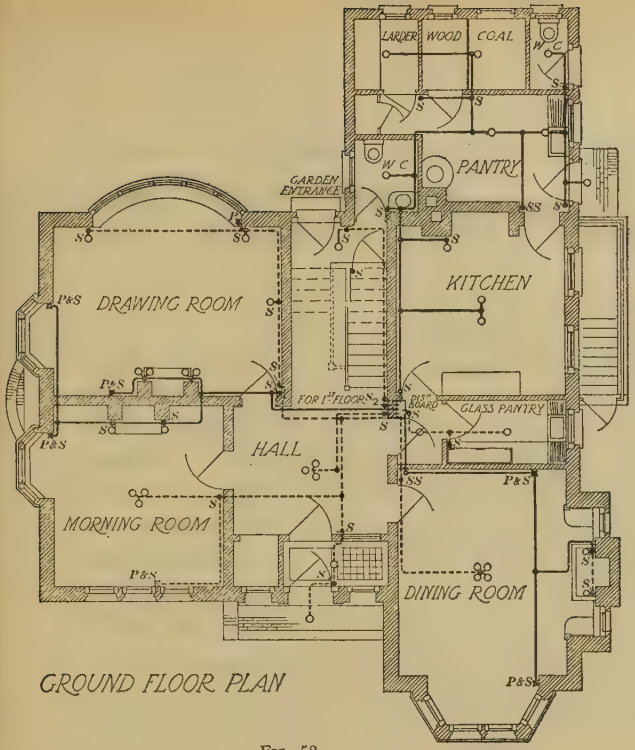

LARDER
WOOD
COAL
W C
PANTRY
GARDEN ENTRANCE
KITCHEN
DRAWING ROOM
FOR 1ST FLOOR
DIS. BOARD
GLASS PANTRY
HALL
MORNING ROOM
DINING ROOM
GROUND FLOOR PLAN

FIG. 58

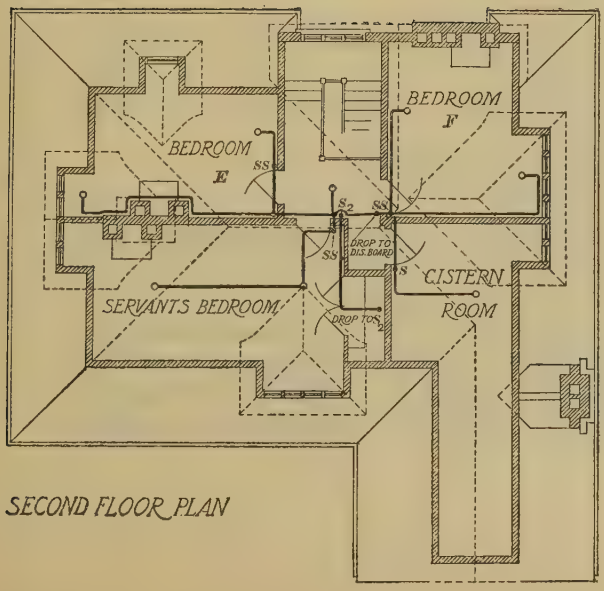
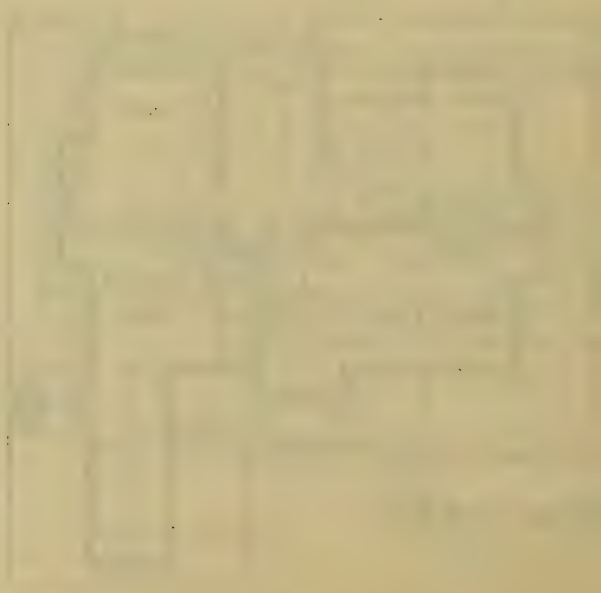

BEDROOM F
BEDROOM E
DROP TO DIS. BOARD
CISTERN ROOM
SERVANTS BEDROOM
DROP TO
SECOND FLOOR PLAN

FIG. 60

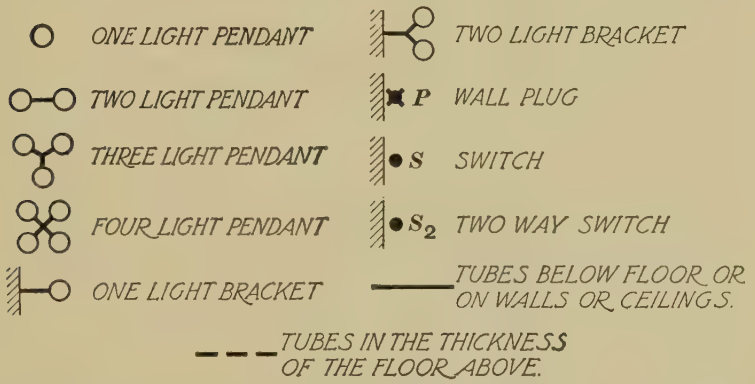


PREPARATION FOR TENDERS

SCHEDULE AND SPECIFICATION

78. Contractors asked to tender for an installation should be provided with plans, showing clearly the position of the lights ; a schedule, giving full details of the number of lights and switches ; and a specification, with which the work must conform. The plans supplied are usually blueprints, and, if desired, their return may be requested with the tender. The greatest care should be taken in the preparation of all three, as a slight ambiguity may result in two entirely different interpretations being put on the clause or figure concerned.

79. Symbols for Wiring Plans.—There are no generally recognized symbols for the marking of wiring plans in Great Britain ; but the following sufficiently indicate the character of the fittings to which they refer :



80. Arrangement of Lights.—The selection of fittings and arrangement of lights on any premises must depend largely on the sum which is to be allowed for the electrical work. The installation suggested in the accompanying plans and schedule are based on the drawings for the house shown in Figs. 57 to 60. It should be regarded as an example, the arrangement being modified to suit individual requirements. If it is not necessary

to consider the expense, the screwed-tube conduit system is undoubtedly the best, and is in fact the only reliable one for

TABLE IV

SCHEDULE OF LIGHTS AND SWITCHES

Position	Description of Fitting	Number of Points	Number of Lights	Number of Switches
	BASEMENT			
Store	1 plain pendant with E.I. shade	1	1	1
Furnace room	1 plain pendant with E.I. shade	1	1	1
	1 wall plug for hand lamp	1	1	
Passage	1 plain pendant with E.I. shade	1	1	1
	GROUND FLOOR			
Dining room	1 special four-light fitting	1	4	2
	2 one-light brackets	2	2	2
	2 wall plugs	2	2	2
Over front door	1 water-tight bracket	1	1	1
Vestibule	1 ornamental lantern	1	1	1
Hall	1 three-light electrolier	1	3	1
Morning room	1 three-light electrolier	1	3	1
	2 one-light brackets	2	2	2
	2 wall plugs	2	2	2
Drawing room	2 two-light brackets	2	4	2
	3 one-light brackets	3	3	3
	3 wall plugs	3	3	2
Passage	1 plain pendant	1	1	1
W.C.	1 plain pendant	1	1	1
Glass pantry	1 plain pendant	1	1	1
Kitchen	1 two-light plain pendant	1	2	1
	1 one-light bracket	1	1	1
Pantry	2 plain pendants	2	2	2
Larder	1 plain pendant	1	1	1
Wood and coal	1 pendant with E.I. shade	1	1	1
W.C.	1 pendant with E.I. shade	1	1	1
Rear entrance	1 water-tight bracket	1	1	1
	FIRST FLOOR			
Landing	1 ornamental pendant	1	1	2 two-way
Bedroom A	2 plain pendants	2	2	2
	1 two-light counterweight pendant	1	2	1
	1 wall plug	1	1	1
Dressing room	1 two-light counterweight pendant	1	2	1
Cupboard	1 plain pendant	1	1	1
Bedroom B	1 two-light counterweight pendant	1	2	1
	2 pendants	2	2	2
	1 wall plug	1	1	1
Bath room	1 plain pendant	1	1	1
Bedroom C	1 two-light counterweight pendant	1	2	1
	2 pendants	2	2	1
	1 wall plug	1	1	1
W.C.	1 plain pendant	1	1	1
Bedroom D	1 two-light pendant	1	2	1
	1 wall plug	1	1	1
	SECOND FLOOR			
Bedroom E	2 plain pendants	2	2	2
Landing	1 plain pendant	1	1	2 two-way
Bedroom F	2 plain pendants	2	2	2
Servant's bedroom	2 plain pendants	2	2	2
Cistern room	1 plain pendant	1	1	1
	Total	63	78	63

damp situations, and for concealed work in new buildings. There is not much choice between close-joint tube and casing, but, on account of its better appearance, the latter is to be preferred for office and residential premises, and the former for factory and similar buildings, where economy is a greater consideration than appearance.

SPECIFICATION FOR AN INSTALLATION OF ELECTRIC LIGHT

81. System.—The installation shall be suitable for a pressure of 200 volts, and shall be carried out on the distributing fuseboard system. At a point as near as possible to the supply company's terminals a double-pole switch and a pair of single-pole fuses shall be provided, and from these a pair of main conductors shall be run to the main distribution board; sub-mains shall be run from this board to the sub-distribution boards in approved positions from which the conductors to the various lights and switches shall extend. The sub-circuits shall, as far as possible, be so arranged that in the event of the blowing of a fuse no room will be left in entire darkness, and unless, in exceptional circumstances, not more than ten lamps of 16 candlepower, or their equivalent, will be permitted on any one circuit.

82. Conductors.—The cross-sectional area of the wire shall in no case be less than that specified in the Rules of the Institution of Electrical Engineers, and must be so proportioned that a drop not exceeding 1 per cent. of the declared pressure shall take place between the respective distribution boards and the most distant light on any circuit. All conductors shall be stranded, and, with the sole exceptions of fitting wires and flexible, nothing smaller than 3/22 S.W.G. will be permitted. No single strand of any conductor shall be larger than No. 16 S.W.G., unless otherwise specified.

83. Insulation.—All conductors shall be well tinned and heavily insulated with pure and vulcanized india-rubber, taped, stoutly braided with flax, hemp, or cotton, and coated with preservative compound. All cable must be by an approved

maker, and shall be delivered on the site in the original coils with label intact. They shall be tested at the maker's works for insulation resistance after 24 hours' immersion in water at a temperature of 60° F. with an E.M.F. of not less than 500 volts. After 1 minute's electrification, the insulation resistance shall not be less than 600 megohms per mile.

84. Joints.—All connections to switches, ceiling roses, etc., shall be made by looping, and no joints shall be used except at the connection of electroliers to the circuit wires and in such other cases as are unavoidable, and then only with the consent of the architect. Where necessary, they must be well and carefully made and properly soldered, resin only being used as a flux. They shall then be thoroughly well insulated with pure rubber strip and solution protected by prepared waterproof tape. All joints must be placed, as far as possible, in easily accessible positions, and joints behind plaster work will under no circumstances be permitted.

85. Protection of Casings.—All casings shall be of well-seasoned American whitewood of thoroughly good quality, double grooved to ensure the proper separation of the lead and return wires throughout their length. The centre fillet to be fully $\frac{1}{2}$ inch in width in the smaller casings, increasing in due proportion for the larger sizes. The covers shall be of neatly moulded pattern, and shall be secured throughout by round-headed brass screws, and not nails. Joints shall be carefully mitred at corners, birdsmouthed at tees, and scarfed in the straight run. Crossings shall be avoided as far as possible, but, where necessary, bridges must be so arranged that the wires are properly enclosed and separated by at least the width of the fillet.

86. Protection of Conduits.—Except where casing is specified, all conductors shall be enclosed throughout their length in solid-drawn or welded steel conduits of not less than No. 16 gauge. The interior of the tubes shall be quite smooth and free from projections, the ends being reamered to remove sharp edges. The joints between the various lengths and fittings shall be

tightly and properly screwed in such a manner that the whole system is electrically continuous. The system shall be efficiently earthed at least at three points to an iron water pipe by means of an insulated copper wire of not less than No. 14 S.W.G.

Suitable draw-in boxes, inspection **T** pieces, and bends shall be provided wherever necessary, the covers being fixed by means of brass screws. All conduits, boxes, and accessories shall be fixed in position before any wires are drawn in, and the number of wires in any conduit, and the number, position, and size of the boxes, shall be so arranged that any wire can be easily drawn out and another drawn in without disturbing the remainder. Where the supply is alternating, the lead and return wires must be enclosed in the same tube. All conduits must be securely fixed by neat saddles screwed to hardwood plugs.

87. Main Switches and Fuses.—The main switches and fuses shall be enclosed in cast-iron or polished-teak cases with hinged cover, glazed front, lever lock, and key.

Switches and fuses of opposite polarity shall be mounted on enamelled slate bases at least $\frac{3}{4}$ inch in thickness, separated by an ebonite dividing fillet, which shall reach as nearly as possible to the front of the case. The holes for the mounting screws must be bushed with ebonite washers. Switches shall be of quick-break, double-pole type, of strong mechanical design, with ample laminated contact surfaces, and shall be capable of conducting the full-load current continuously without heating. No hinges or pivots shall be used for conducting currents. The fuses shall be of the spring-clip, porcelain-handle replacement pattern. All main connections to switches, fuses, and distribution boards shall be neatly made by sweated thimbles at the front of the panels, the cases being mounted at least 2 inches away from the wall on hardwood battens.

88. Distribution Boards.—All fuseboards shall be fitted with copper bus-bars and phosphor-bronze spring clips of ample carrying capacity, mounted on enamelled slate bases in teak cases, in the manner described for the main switches. The fuses shall be of the tubular-porcelain replacement type with a break of not less than $1\frac{1}{2}$ inches. A varnished card shall be supplied

with each board, showing the position of the lights controlled by the fuses.

89. Sub-Switches.—All branch switches shall be of the quick-break tumbler type on glazed porcelain bases with fluted bronze or brass covers.

90. Ceiling Roses.—Ceiling roses shall be of the looping-in pattern with glazed porcelain bases and covers, and must contain porcelain bridges arranged to take the weight of the fitting off the terminals.

91. Lampholders.—Lampholders are to be of the bayonet-socket pattern with heavy brass exterior. The interiors are to be of glazed porcelain, with an efficient bridge between the contacts. All cord grips must be of the non-twisting pattern.

92. Wall Sockets.—All wall plugs must be interchangeable and of the two-pin type, with glazed porcelain bases and covers. They must be so constructed that a short circuit by accidental contact with metal shall be impossible. Each wall plug must be controlled by a single-pole tumbler switch placed directly above it.

93. General.—Ceiling roses, branch switches, wall plugs, and similar accessories must not be mounted direct on the wall, but shall be fixed to a polished hardwood recessed block secured to the wall by means of screws in hardwood plugs, the accessory being separately screwed to the block. The insulation of the conductors shall be carried through the block and porcelain base as close to the terminal as possible. The whole of the work under this specification must comply with the rules of the supply authority and fire insurance company concerned.

The contractor shall be responsible for all structural and decorative damage to property and for the injury caused by the works or workmen to persons, animals, or things, and shall hold the employer harmless in respect thereof. He shall also be entirely responsible for any and all claims that may be made under any Workmen's Compensation Act, or other Act of Parliament that may now be in force, or that may come into force during the period of the continuation of this contract.

ELECTRIC BELL WIRING

FITTINGS AND WORKMANSHIP

94. Electromagnets. — If a wire is wound round an iron *core*, as shown in Fig. 61, and an electric current flows through the wire round the core as indicated by the arrowheads, the core will become a magnet and will attract magnetic substances. A magnet so formed is called an **electromagnet.** Electromagnets are frequently made in the form of a horseshoe, or **U** shape, as shown in Fig. 62, where the magnet consists of two cores *M*, *M*, magnetizing coils *c*, an iron yoke *b*, and an iron armature *a*. In the illustration, one-half of the electromagnet is shown in section. The yoke is rigidly fastened to one end of each core, and in some cases the cores and yoke are made in one solid piece. When a current is flowing through the coils, the armature is held firmly to the cores by magnetic attraction ; when no current is flowing, the attraction ceases.

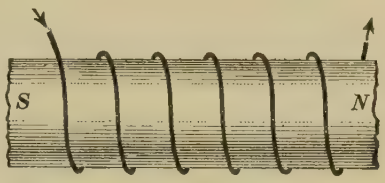


FIG. 61

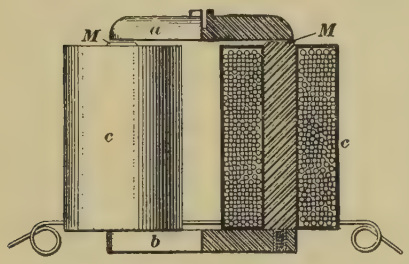


FIG. 62

95. Electric Bells.—Formerly electric bells were a luxury, but have now become a convenience and a necessity. Few dwellings, office buildings, hotels, factories, etc., are without them. Interior bell-wiring systems are of all stages of complexity, from the simplest door bell to the complex signalling systems of large

hotels. Putting in bell-wiring systems is a comparatively simple matter, and yet, if it is not properly done, the system may become a source of trouble, annoyance, and even danger, instead of a convenience.

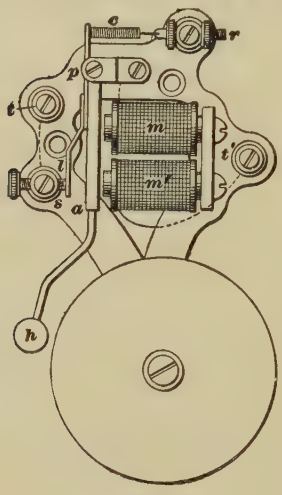


Fig. 63

96. The action of an electric bell may be explained by referring to Fig. 63. The terminals to which wires are connected are at t, t'. The electric current enters at t and passes through the mechanism by way of the adjustment screw s–the spring l–the pivot p–the electromagnets m, m'–out at terminal t'. As soon as current passes through the magnets, the armature a is drawn toward the magnets and the hammer h strikes the bell. The movement of the armature causes spring l to break contact with screw s, and the flow of current ceases. This causes the magnets to lose their attractive power, so that spring c, which may be adjusted by screw r, draws the armature away from the magnets, and contact is again made between the spring l and the screw s. Current again flows through the magnets and the hammer h again strikes the bell, etc., these actions being repeated in quick succession until the circuit is opened at some other point. Every time contact is broken between s and l, a spark occurs, and most metals would soon become so burnt that they would not make good electrical contact; to prevent this, the contact points are tipped with platinum, which is not easily injured by heat.

97. Trembler and Single-Stroke Bells.—The bell just described is an illustration of **trembler bells**; in another class, called **single-stroke bells**, the hammer strikes the bell only one blow each time the circuit is closed at the push button, or switch. No automatic contact-breaker is necessary in a single-stroke bell. The bell shown in Fig. 63 could be made single-stroke by changing one wire connection from terminal t direct to magnet m, or by

connecting a piece of wire from t across to p. Single-stroke bells are usually so adjusted that the hammer moves through a considerable distance and strikes the bell a hard blow.

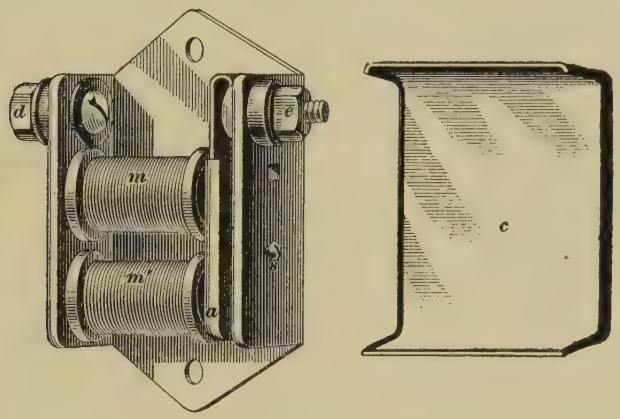
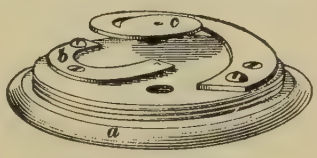


FIG. 64

98. Buzzers.—In places where the noise of an electric bell would be objectionable, a **buzzer** may be used Fig. 64 shows a buzzer with the cover c removed. The wires are connected to terminals d, e; m, m' are the magnets, and a is the armature, which is adjusted by means of screw s. When current is flowing, the armature vibrates rapidly, and thus causes a buzzing sound.



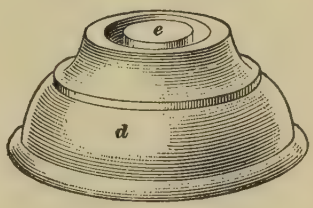


FIG. 65

99. Push Buttons.—Bell-ringing circuits are usually closed, and the bells are rung by means of a **push button**, also called a **push**, a very simple form of which is shown in Fig. 65. The wires are brought through a hole in the wooden base a and connected to contact springs b, c. When the cap d is screwed into place over the base, the button e is held in place by the spring c. A slight pressure on this button forces contact spring c against contact b, thus closing the circuit.

Push buttons are made in a great variety of styles and finish. The one shown in Fig. 65 is the cheapest kind of wooden button. Buttons may be had of the same general form, but with ornamental metal caps; or, if desired, buttons mounted on beauti-

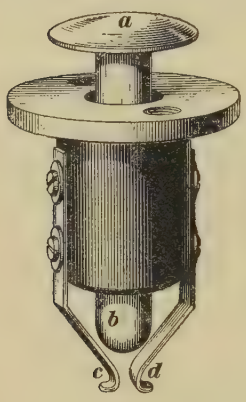


Fig. 66

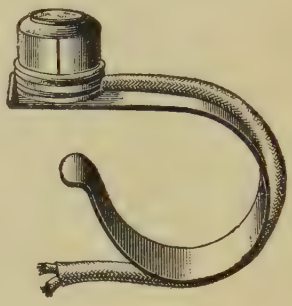


Fig. 67

fully engraved bronze plates with spaces arranged for names may be obtained. Smaller pushes, or springs, are made for mounting in the casings of doors or windows, so that the opening of a door or the raising of a window will close a contact and ring a bell. Fig. 66 shows a floor push, for mounting in the floor underneath a table so that a slight foot pressure on the cap *a* will force the plunger *b* into contact with springs *c*, *d*, thus closing a circuit and causing a bell to ring. Fig. 67 shows a push with a clamp for fastening to the edge of a table or a desk.

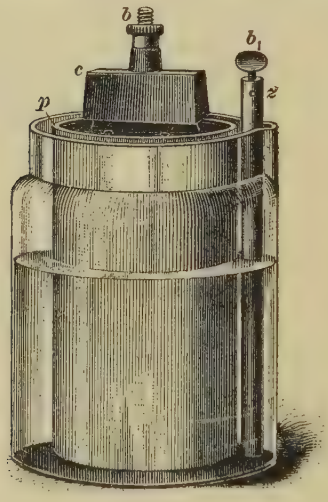


Fig. 68

100. Sources of Current.—It requires but very little current at a low pressure to ring an electric bell, and voltaic cells are nearly always used as the source of current. The cells most used are those of the *open-circuit type*, which will furnish current for

short intervals only and will run down if used continuously. Fig. 68 shows a Leclanché cell, a type much used for bell ringing, in which b, b' are the terminals, c the carbon element contained in a porous cup p, and z the zinc element. The space surrounding the carbon element inside of the porous cup is filled with a chemical substance mixed with crushed carbon. The chemical absorbs or unites with the free hydrogen gas that would otherwise gather on the surface of the carbon, and thus acts as a depolarizer.

101. Indicators.—An **indicator** is a device inserted in a bell circuit for the purpose of showing automatically the position of the push that is causing the bell to ring. The general appearance and the construction of a **pendulum** indicator is shown in Fig. 69 (*a*) and (*b*). One *movement hole*, as it is commonly called, is provided on the indicator board for each push point, the name of the place where the push is situated being given on the glass above the hole. The coil of the electromagnet *a*, shown in

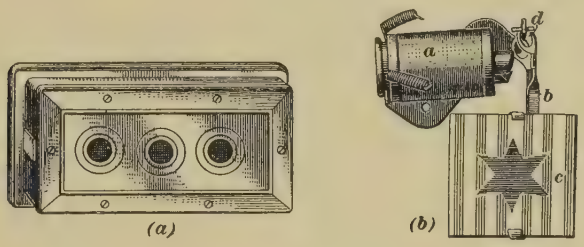


FIG. 69

view (*b*), is in series with its respective push, the battery, and the bell, so that every time the bell is rung from that particular push the armature *b*, which is of soft iron, is attracted to the core of the electromagnet and falls back when the push is released. The screen *c* is attached to the armature, and as the whole is freely pivoted at *d*, a swinging motion is set up which gives an indication of the room from where the bell has been rung.

102. Hand-Replacement Indicators.—In another form of indicator, known as the hand-replacement type, the signal remains down until it is reset by hand, thus informing the attendant which push has been used, even though he should not

see the indicator until some time after the bell has been rung. This type of indicator is illustrated in Fig. 70 (*a*) and (*b*). The holes are normally clear, but when the current passes through the coil *a*, the *screen b*, which is painted red, is released by the *trip c* and falls in front of its respective hole, where it remains

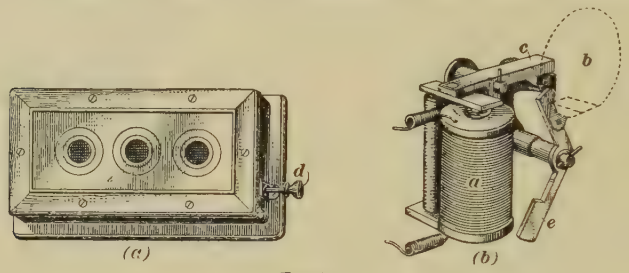


FIG. 70

until it is reset by means of the handle *d*, shown in (*a*), which is at the end of a rod that slides through the indicator case, and has a special attachment by means of which, when the rod *d* is pushed, the arm *e* of the screen, shown in (*b*), can be worked so as to draw back the screen until it is caught by the trip *c*.

BELL-WIRING CIRCUITS

103. Fig. 71 shows a system of bell wiring with no indicator,

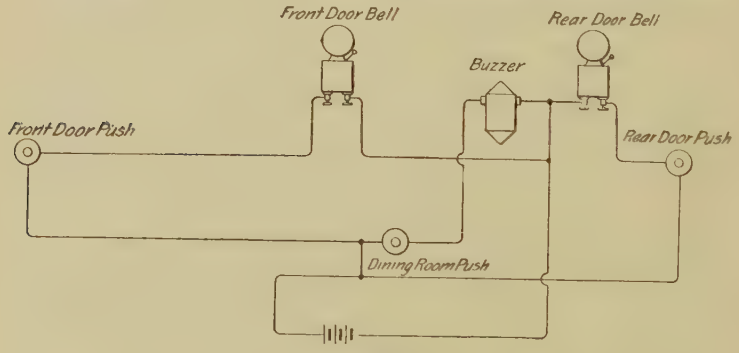


FIG. 71

which is suitable for a small dwelling. Fig. 72 shows connections for a simple indicator system. The pushes *1*, *2*, *3*, etc., are placed

at convenient points in the various rooms, or at outside doors. One terminal of each push is connected to the common *battery wire b*, which goes to one battery terminal. The other terminal of each push is connected by a *leading wire l* to the proper electro-magnet in the indicator, whence a wire goes to one bell terminal. The other bell terminal is connected to the other battery terminal. The battery *B* may have any convenient and accessible location where it will not be exposed to excessive moisture.

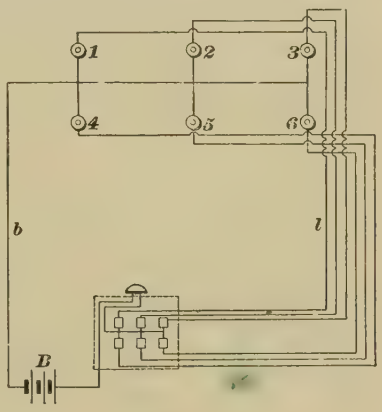


FIG. 72

INSTALLING BELL WIRES

104. No. 20 S.W.G. wire covered with two layers of cotton treated with paraffin is generally used for bell-wire circuits in dry places. For good work, or where dampness is present, wires enclosed in zinc or steel tubes should be used ; if the wires are to be exposed to much moisture, they should be rubber-covered. If considerable current is to be carried on a wire, as on the main battery wire in a large system, it will pay to use No. 18 S.W.G., so as to obtain less resistance.

105. There are not many regulations for putting up electric-bell wires. The wires must be neatly arranged and securely fastened in place in some convenient workmanlike manner. They must not come nearer than 6 inches to any electric-light or power wire in the building unless they are encased in approved tubing. When bunched together in any building, bell wires must have a fire-resisting covering or else be encased in a non-combustible tube or shaft. They should not be in the same tube with electric-light or power wires, and, if in the same shaft, must be kept at least 2 inches from such wires. Wire ducts or shafts must be

thoroughly stopped at each floor or wall to prevent the spread of fire. Push-button and electric-light switches should not be mounted on the same wall plate. If it is desirable for the sake of appearance that the two should be together, special precautions must be taken that no leakage can take place from one circuit to the other.

106. Staples. — Bell wires are often stapled to woodwork. The staples should not be driven hard, and both wires should not be fastened under one bare staple, but special insulated staples, as shown in Fig. 73, may be so used. In new buildings, the bell wires can be grouped and run through holes in the woodwork, thus avoiding the use of staples. In the best class of work, bell wires are run in conduits. All bell circuits, when complete, should be tested for breaks, earths, and short circuits.

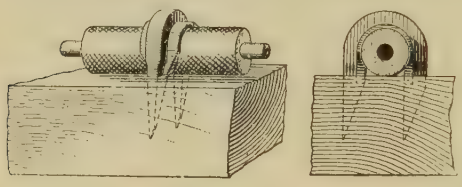


FIG. 73

A SERIES

OF

QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS

TREATED OF IN THIS VOLUME.

The following Examination Questions are divided into sections corresponding to the text, so that each section has a head-line which is the same as that of the section to which the questions refer.

No attempt should be made to answer the questions or to solve the examples until the corresponding part of the text has been carefully studied.

JOINERY

(PART 1)

EXAMINATION QUESTIONS

(1) What two classes of joints are used in joinery?

(2) Why is a sliding door hung at the top preferable to a door hung at the side?

(3) Mention a piece of work in which a half-lap dovetail joint would be serviceable.

(4) Should wet steam or superheated steam be used for bending wood?

(5) In veneering a door, of what material is the core of the stile usually composed?

(6) Are dowels used for butt joints?

(7) Name five methods of bending wood?

(8) What is a veneer?

(9) What is a framed ledged and braced door?

(10) What are the objections to saw kerfing?

(11) What is a caul?

(12) Sketch a ledged and braced door.

(13) How is a caul prevented from sticking to the veneer?

(14) Mention two ways of hanging a door to linings, and sketch an example of each.

(15) It is required to bend a white-pine plank round a cylinder having a diameter of 15 feet. What thickness of plank may be used without steaming or other preparation?

(16) Sketch three examples of finishings to door panels.

(17) (*a*) What is matched boarding ? (*b*) Sketch an example.

(18) Sketch the plan of a door for an entrance to a house.

(19) Sketch the meeting of a pair of folding doors.

(20) Sketch a door, and show the following : (*a*) lock rail ; (*b*) muntin ; (*c*) stile ; (*d*) top rail ; (*e*) bottom rail ; (*f*) panel.

JOINERY

(PART 2)

EXAMINATION QUESTIONS

(1) What is the name of the strip that separates the upper and lower sashes of a balanced sash window ?

(2) What is a mullion ?

(3) Why should joinery finishings be secured to plaster grounds in preference to being attached to the wall directly against the plastered surface ?

(4) What parts of a hung sash window frame should be made movable in order to fit and hang the sashes ?

(5) How is access gained to a weight box for renewing a sash cord ?

(6) How may drawers be made so as not to sag when pulled out ?

(7) What is a transom ?

(8) Sketch the lower rail and sill of a double-hung sash window, and point out the particular precautions to be taken to render it water-tight.

(9) What is meant by the term architrave ?

(10) Sketch the plan through the jamb of a casement window to open outwards.

(11) Into what general classes may sashes be divided ?

(12) (*a*) What is a skirting ? (*b*) Sketch the sections through two examples.

(13) Sketch a section through the mullion between two double-hung sash windows.

(14) Draw two methods adopted in making the meeting stiles between casement sashes.

(15) Draw six types of stock mouldings and name each.

(16) How may a skirting be stopped against an architrave ?

(17) Draw a plan of a sash box and mark the following parts : Inside and outside linings, pulley stile, parting bead, and parting slip.

(18) Name the different ways in which a casement window may be hung.

(19) What is an astragal ?

(20) How is an architrave jointed at its upper corner ?

STAIR BUILDING

EXAMINATION QUESTIONS

(1) (*a*) Define riser, tread, and step. (*b*) What is meant by flight and by landing ?

(2) (*a*) What are balusters ? (*b*) When are they fixed to the tread, and when to the string ? (*c*) How many balusters are generally set on each tread ? (*d*) Why are balusters with square bases preferable to those with round bases ?

(3) (*a*) How should the finished work on a staircase be protected during the construction of the building ? (*b*) To what are creaking noises in the staircase due ?

(4) What are fliers and winders ?

(5) (*a*) Why is the number of treads in each flight one less than the number of risers ? (*b*) A riser has a height of 7 inches ; determine the width of the tread by rules I and II, Art. **9.**

(6) What is the proper height for a riser in order to ensure easy stepping ?

(7) Describe two methods of arranging the treads in an elliptic staircase.

(8) Given a tread of 9 inches, determine the height of the riser by rule III, Art. **9.**

(9) How are landings supported in frame and brick walls ?

(10) (*a*) What are the common lengths of pin balusters ? (*b*) When two balusters are placed on one tread, how should they be arranged ?

(11) (*a*) To what depth are the risers and treads usually housed ? (*b*) In geometrical staircases, how are the rails supported ?

(12) (*a*) What is a newel? (*b*) Where are starting and angle newels usually placed?

(13) Name the materials of which staircases are constructed, and state when each should be used.

(14) (*a*) Mention the principal points to be considered in designing a staircase. (*b*) Give the minimum widths of staircases in public and private buildings.

(15) (*a*) Mention some points to be considered in setting the hand rail. (*b*) What is a ramped hand rail, and what is its object? (*c*) When a continued hand rail is used, how may it be braced or stiffened?

(16) (*a*) What is a goose neck? (*b*) What is a swan neck? Sketch an example of each.

(17) (*a*) What is the least headroom required? (*b*) How can the headroom be ascertained?

(18) What is the difference in the method of fixing treads and risers, in an open string and a close string?

(19) Describe the method of forming a wreath on a close string.

(20) Sketch varieties of moulded hand rails, and describe how the joints are made when it becomes necessary to join two lengths of hand rail together.

IRONMONGERY

EXAMINATION QUESTIONS

(1) What is the use of the knuckle butt hinge?

(2) Describe and illustrate a method of operating a fanlight with opening gear.

(3) What is the difference between a rim and a mortise lock?

(4) What is the difference between a cut and a wire nail?

(5) What is bronze?

(6) How are nails galvanized?

(7) What is an Espagnolette bolt?

(8) Explain a master-key lock of the Yale type.

(9) (*a*) What is the follower of a lock? (*b*) What are the wards and what is their use?

(10) How are wood screws measured?

(11) What forms of cast-iron hinges are there?

(12) Describe a good form of stair tread.

(13) How is a door knob attached to its spindle?

(14) Describe the form and action of some good form of sliding-door runner.

(15) Describe two good forms of sash fasteners.

(16) Describe a good form of gate hinge for a gate which opens both ways.

(17) How should the folding doors of a coach house be fastened and locked?

(18) What are the advantages of rising butts?

(19) What are the different forms of stay that may be used with a side-hung casement?

(20) (*a*) What different forms of grip handles for swing doors are there? (*b*) What kind should be chosen for a narrow stile, and why?

PLASTERING

EXAMINATION QUESTIONS

(1) What is fine stuff?

(2) Describe the method of making cornices.

(3) What are the usual dimensions of wooden laths?

(4) What is plaster of Paris and how did it get its name?

(5) Why are wooden laths nailed so as to leave a space between them?

(6) What is fibrous plaster and how is it used?

(7) What are the advantages of hard plasters?

(8) Define and describe floating coat,

(9) What is the advantage of metal lathing over wooden laths?

(10) What are screeds?

GLASS AND GLAZING

EXAMINATION QUESTIONS

(1) What is rough-cast plate glass, and for what situations is it used ?

(2) Name five varieties of obscured, or partially obscured, glass.

(3) What process is adopted in the manufacture of sheet glass ?

(4) In what three varieties is wired glass made ?

(5) Describe the method of polishing plate glass.

(6) How is ambitti sheet glass manufactured ?

(7) What is meant by electro-copper glazing, and what is its principal use ?

(8) Of what is glaziers' putty manufactured ?

(9) What are slab, or bottle, glasses ?

(10) Illustrate by means of a sketch one system of glazing a roof-light without putty.

PAINTING AND DECORATING

(PART 1)

EXAMINATION QUESTIONS

(1) What advantage has creosote stain over paint for ordinary work ?

(2) What is : (*a*) burnt umber ? (*b*) raw sienna ?

(3) How may paint be ground on a small scale ?

(4) (*a*) What is carmine ? (*b*) What are lakes ?

(5) What are the largest sizes of paint brushes termed ?

(6) How is white lead manufactured by the Dutch process ?

(7) With what is white lead most frequently adulterated ?

(8) (*a*) What is zinc white ? (*b*) When is it used for house painting ?

(9) How may large brushes be preserved when not in use ?

(10) What is : (*a*) ivory black ? (*b*) lampblack ?

(11) How may the quality of linseed oil be tested ?

(12) How many coats of paint should all new woodwork receive ?

(13) Describe : (*a*) knotting ; (*b*) stopping ; (*c*) priming.

(14) What function does oil fulfil in paints ?

(15) What is red lead ?

(16) What is varnish ?

(17) What is : (*a*) a primary colour ? (*b*) a secondary colour ? (*c*) a tertiary colour ?

(18) What is : (*a*) a vehicle ? (*b*) a drier ?

(19) (*a*) What is a pigment ? (*b*) how are they divided into classes ?

(20) Describe, briefly, the process of fuming.

PAINTING AND DECORATING

(PART 2)

EXAMINATION QUESTIONS

(1) What special tools are used to imitate the graining of wood?

(2) What is a piece of wallpaper?

(3) What is distempering?

(4) (*a*) What are stencil plates? (*b*) How are they used?

(5) In gilding over painted work, why are whitening and the white of egg used?

(6) Describe, briefly, the process of graining to imitate gnarled oak.

(7) In interior decoration, where may stencilled work be applied with advantage?

(8) What precautions should be taken when hanging papers on a damp wall?

(9) (*a*) What is whitewash? (*b*) What is limewash?

(10) Describe, briefly, the way to cut stencils and the material from which they are made.

(11) Describe, briefly, the process of imitating black and gold marble.

(12) Describe the process of stencilled inlay.

(13) How should walls be prepared for papering?

(14) What is clear-cole?

(15) What are skewings?

(16) What advantage has graining over plain painting?

(17) Describe the process of hanging heavy relief papers.

(18) What is : (*a*) a mottler ? (*b*) a badger softener ?

(19) (*a*) What is a pulp paper ? (*b*) What is a flock paper ?

(20) How is paperhangers' paste made ?

ELECTRIC WIRING AND BELLS

(PART 1)

EXAMINATION QUESTIONS

(1) Name the units of current, resistance, and electromotive force and state the law governing them.

(2) (*a*) What is meant by electric resistance and conductance? (*b*) State the formula governing the resistance of a conductor as regards its dimensions and the substance of which it is composed.

(3) What is meant by electric potential?

(4) Name in technical language the parts of a voltaic cell.

(5) (*a*) What are the practical units of power and energy? (*b*) Give two formulæ for finding W.

(6) What is meant by (*a*) a closed circuit, (*b*) an earth, (*c*) a short circuit, (*d*) an internal circuit?

(7) Give a brief definition and a rough sketch of (*a*) a series circuit, (*b*) a parallel circuit, (*c*) a series-parallel circuit.

(8) What are the relations between total current and the current in the parts, total electromotive force and the electromotive force in the parts, total resistance and the resistance of the parts, of (*a*) a series circuit, (*b*) a parallel circuit?

(9) In a closed circuit the electromotive force is 112 volts and the total resistance is 50 ohms; what is (*a*) the current, in amperes; (*b*) the power absorbed, in watts?

Ans. { (*a*) 2·24 amperes
(*b*) 251 watts, nearly

(10) The separate resistances of two branches a and b of a divided circuit are 49·2 and 67 ohms, respectively; if the sum of the currents in the two branches is ·76 ampere, what is the current in each branch?

Ans. $\begin{cases} \text{Current in branch } a = \cdot 4382 \text{ ampere} \\ \text{Current in branch } b = \cdot 3218 \text{ ampere} \end{cases}$

ELECTRIC WIRING AND BELLS

(PART 2)

EXAMINATION QUESTIONS

(1) State briefly the preparation of conductors for a joint.

(2) What are the proper positions for (*a*) a main switch; (*b*) the sub-switches; (*c*) pendants for general lighting?

(3) Describe the action of an electric bell.

(4) What are the chief points to be considered in designing an installation and what rules should be complied with?

(5) A pair of cables is to be installed in a factory to carry current, for one hundred 16-candlepower 110-volt lamps, the efficiency of which is 3·1 watts per candlepower, from the dynamo room to a centre of distribution situated in another building; the distance one way is 150 yards and the drop is to be limited to 3 volts: (*a*) What size cable will be required? (*b*) What size would the cables have to be if the Institution of Electrical Engineers' rules for carrying capacity alone were considered?

Ans. { (*a*) 37/16
(*b*) 19/18

(6) (*a*) Under what circumstances should the use of close-joint conduit, and casing alone be permitted? (*b*) Describe two methods of securing electrical continuity in the close-joint system.

(7) Describe with sketches (*a*) the distribution-board system; (*b*) the looping-in system.

(8) In open wiring in dry places, how far should the wires be kept from each other and from the surfaces wired?

(9) (*a*) What are the requirements of a fuse, or cut-out ? (*b*) What are the proper positions for the main fuses and the sub-fuses of an installation ?

(10) Describe briefly the construction of a rubber-insulated electric cable.

(11) State the advantages to be gained by the use of two-way tumbler switches and give a diagram of connections.

(12) (*a*) What useful purpose does a transformer serve in modern installation work ? (*b*) Give a diagram of the connections of an autotransformer.

(13) Give sketches showing the proper means to be adopted in making (*a*) an ordinary **T** joint ; (*b*) a sunk **T** joint ; and (*c*) a vertical and horizontal crossing, in casing.

(14) Give a diagram showing the connections of a four-push bell circuit with indicator.

(15) (*a*) To what tests should an installation be subjected ? (*b*) What instrument is required for this purpose ?

(16) Into what general classes may modern wiring-erection systems be divided ?

(17) Give a sketch of the main connections of a building supplied on the three-wire system.

(18) Describe the construction of a distribution board.

(19) Describe (*a*) the wooden casing usually employed in electrical work, and (*b*) describe the preparation it should undergo before being fixed.

(20) What is the construction of a plain counterweight pendant ?

ANSWERS

TO THE

QUESTIONS AND EXAMPLES

INCLUDED IN THE

EXAMINATION QUESTIONS

Each Key, or set of Answers, has the same section number as the corresponding set of Examination Questions. All references are to the portion of the text that bears the same section number as the Key in which the references occur, unless the title of some other part of the text is mentioned.

To be of the greatest value, the Key should be consulted sparingly, much in the same manner as a pupil would go to a teacher for assistance in solving a problem he is unable to master unaided. The Key should not be referred to except as a last resource, when the student has failed, after using every reasonable effort, to solve the example or answer the question. If used in this way, the Key will be a help and a source of encouragement in studying the various subjects comprising the Course.

JOINERY

(PART 1)

(1) See Art. **4.**

(2) See Art. **63.**

(3) See Art. **14.**

(4) See Art. **36.**

(5) See Art. **40.**

(6) See Art. **7.**

(7) See Art. **30.**

(8) See Art. **37.**

(9) See Art. **54.**

(10) See Art. **31.**

(11) See Art. **39.**

(12) See Art. **52.**

(13) See Art. **39.**

(14) See Art. **67.**

(15) See Art. **36.** Diameter = 15 ft.; therefore, radius = 7 ft. 6 in.
Then, $7\frac{1}{2}$ ft. × ·05 = ·375, or $\frac{3}{8}$ in. Ans.

(16) See Art. **58.**

(17) See Art. **21.**

(18) See Art. **66.**

(19) See Art. **65.**

(20) See Art. **59.**

JOINERY
(PART 2)

(1) See Art. **3.**
(2) See Art. **8.**
(3) See Art. **67.**
(4) See Arts. **3** and **4.**
(5) See Art. **6.**
(6) See Art. **93.**
(7) See Art. **8.**
(8) See Arts. **4** and **5** and Fig. 2 (*c*).
(9) See Art. **68.**
(10) See Fig. 13 (*a*).
(11) See Art. **2.**
(12) (*a*) See Art. **71.**
(*b*) See Fig. **29.**
(13) See Art. **8** and Fig. **4.**
(14) See Fig. 13 (*c*) and (*d*).
(15) See Art. **83** and Fig. **32.**
(16) See Art. **38.**
(17) See Fig. 2 (*b*).
(18) See Art. **28.**
(19) See Art. **4.**
(20) See Art. **69.**

STAIR BUILDING

(1) (*a*) and (*b*) See Art. **3.**

(2) (*a*), (*b*), and (*c*) See Art. **20.**

(3) (*a*) and (*b*) See Art. **25.**

(4) See Art. **3.**

(5) (*a*) See Art. **9.**

(*b*) By rule I, height of riser is 7 in., then $66 \div 7 = 9\frac{3}{7}$, or $9\frac{1}{2}$ in., width of tread. Ans. By rule II, height of riser is 7 in., then $7 + 5 = 12$, and $5 \times 2 = 10$ in., the width of the tread. Ans.

(6) See Art. **8.**

(7) See Art. **69.**

(8) By rule III, Art. **9,** draw the triangle, as shown in Fig. 5, to scale and measure the width of tread 9 in. from *a* on line *a b*, as at *a c*; at *c* erect a perpendicular cutting the hypotenuse at *e*. Measure *e c*, when it will be found to be 6·875 in., or the height of the riser required.

(9) See Art. **18.**

(10) (*a*) and (*b*) See Art. **20.**

(11) (*a*) and (*b*) See Art. **5.**

(12) (*a*) and (*b*) See Art. **19.**

(13) See Art. **2.**

(14) (*a*) and (*b*) See Art. **1.**

(15) (*a*) See Art. **21.**
(*b*) See Art. **22.**
(*c*) See Art. **23.**

(16) (*a*) and (*b*) See Art. **22.**

(17) (*a*) and (*b*) See Art. **10.**

(18) See Art. **6.**

(19) See Art. **44.**

(20) See Art. **21.**

IRONMONGERY

(1) See Art. **39.**
(2) See Arts. **143** to **148.**
(3) See Art. **63.**
(4) See Arts. **5** and **7.**
(5) See Art. **26.**
(6) See Art. **16.**
(7) See Art. **139.**
(8) See Arts. **80** and **81.**
(9) (*a*) and (*b*) See Arts. **64** and **65.**
(10) See Art. **19.**
(11) See Art. **33.**
(12) See Art. **151.**
(13) See Arts. **105** to **108.**
(14) See Arts. **54** to **60.**
(15) See Art. **130.**
(16) See Art. **61.**
(17) See Art. **98.**
(18) See Art. **37.**
(19) See Art. **136.**
(20) See Art. **115.**

PLASTERING

(1) See Art. **25.**
(2) See Arts. **51** and **52.**
(3) See Art. **8.**
(4) See Art. **22.**
(5) See Art. **9.**
(6) See Art. **34.**
(7) See Art. **33.**
(8) See Art. **46.**
(9) See Art. **10.**
(10) See Art. **47.**

GLASS AND GLAZING

(1) See Art. **6.**
(2) See Arts. **12** to **19.**
(3) See Art. **3.**
(4) See Art. **24.**
(5) See Art. **9.**
(6) See Art. **21.**
(7) See Art. **42.**
(8) See Art. **29.**
(9) See Art. **22.**
(10) See Arts. **38** to **41.**

PAINTING AND DECORATING
(PART 1)

(1) See Art. **82.**

(2) (*a*) See Art. **53.**
(*b*) See Art. **55.**

(3) See Art. **84.**

(4) (*a*) See Art. **11.**
(*b*) See Art. **10.**

(5) See Art. **90.**

(6) See Art. **12.**

(7) See Art. **18.**

(8) (*a*) and (*b*) See Art. **19.**

(9) See Art. **92.**

(10) (*a*) See Art. **22.**
(*b*) See Art. **21.**

(11) See Art. **60.**

(12) See Art. **97.**

(13) (*a*) See Art. **94.**
(*b*) See Arts. **95** and **96.**
(*c*) See Art. **97.**

(14) See Art. **58.**

(15) See Art. **27.**

(16) See Art. **68.**

(17) (*a*) See Art. **2.**
(*b*) See Art. **3.**
(*c*) See Art. **3.**

(18) (*a*) See Art. **58.**
(*b*) See Art. **65.**

(19) (*a*) See Art. **8.**
(*b*) See Art. **9.**

(20) See Art. **81.**

PAINTING AND DECORATING

(PART 2)

(1) See Arts. **4** to **9.**

(2) See Art. **51.**

(3) See Art. **35.**

(4) (*a*) and (*b*) See Arts. **24** and **26.**

(5) See Art. **46.**

(6) See Art. **14.**

(7) See Arts. **31** to **34.**

(8) See Art. **55.**

(9) (*a*) and (*b*) See Art. **37.**

(10) See Art. **25.**

(11) See Art. **23.**

(12) See Arts. **32** to **34.**

(13) See Arts. **54** and **55.**

(14) See Art. **38.**

(15) See Art. **48.**

(16) See Art. **10.**

(17) See Art. **54.**

(18) (*a*) See Art. **8.**
(*b*) See Art. **9.**

(19) (*a*) and (*b*) See Art. **52.**

(20) See Art. **54.**

ELECTRIC WIRING AND BELLS

(PART 1)

(1) See Arts. **22** and **23.**

(2) See Arts. **4, 5,** and **21.**

(3) See Art. **9.**

(4) See Art. **14.**

(5) See Arts. **37, 38,** and **41.**

(6) See Art. **43.**

(7) See Arts. **45, 49,** and **58.**

(8) See Arts. **45** to **53.**

(9) (*a*) By Ohm's law, Art. **25,**

$$C = \frac{E}{R} = \frac{112}{50} = 2{\cdot}24 \text{ amperes.} \quad \text{Ans.}$$

(*b*) From Art. **37,**

$$W = E\,C = 112 \times 2{\cdot}24 = 251 \text{ watts, nearly.} \quad \text{Ans.}$$

(10) Let C_1 and C_2 = current in branches *a* and *b*, respectively, and find them according to Art. **50.** From the problem the total current $C = {\cdot}76$, $r_1 = 49{\cdot}2$, $r_2 = 67$. $\frac{C_1}{C_2} = \frac{r_2}{r_1}$, or $\frac{C_1}{C_2} = \frac{67}{49{\cdot}2}$. $C_1 = {\cdot}76 - C_2$. Substituting, $\frac{{\cdot}76 - C_2}{C_2} = \frac{67}{49{\cdot}2}$. Clearing of fractions, $49{\cdot}2 \times ({\cdot}76 - C_2) = 67\,C_2$. Transposing and uniting terms, $116{\cdot}2\,C_2 = 37{\cdot}392$.

$37{\cdot}392 - 49{\cdot}2\,C_2 = 67\,C_2$. $C_2 = \frac{37{\cdot}392}{116{\cdot}2} = {\cdot}3218$ ampere in branch *b*. Ans.

$C_1 = {\cdot}76 - {\cdot}3218 = {\cdot}4382$ ampere in branch *a*. Ans.

ELECTRIC WIRING AND BELLS

(PART 2)

(1) See Art. **16.**

(2) (*a*) See Art. **29.**
(*b*) See Art. **29.**
(*c*) See Art. **49.**

(3) See Art. **96.**

(4) See Arts. **1** and **2.**

(5) (*a*) According to Art. **4,** the total power in watts $= 3{\cdot}1 \times 16 \times 100 = 4{,}960$; and as amperes $= \frac{\text{watts}}{\text{volts}}$, the current carried by the conductors is $\frac{4{,}960}{110} = 45$ amperes.

$R = \frac{E}{C} = \frac{3}{45} = {\cdot}067$ ohm, the resistance of the circuit, or $2 \times 150 = 300$ yd. The resistance per 1,000 yd. $= \frac{{\cdot}067}{300} \times 1{,}000 = {\cdot}225$ ohm.

On reference to Table I, it is seen that 37/16 is the smallest cable having a resistance of less than ·223 ohm per 1,000 yd. Therefore, 37/16 is the required cable. Ans.

(*b*) If simply carrying capacity is to be considered, it is seen from Table I that 19/18 is the required cable. Ans.

(6) (*a*) See Arts. **68** and **71.**
(*b*) See Art. **71.**

(7) (*a*) See Art. **62.**
(*b*) See Art. **61.**

(8) See Art. **64.**

(9) (*a*) See Art. **31.**
(*b*) See Art. **36.**

(10) See Art. **8.**

(11) See Art. **27.**

(12) (*a*) See Art. **57.**
(*b*) See Art. **59.**

(13) (*a*), (*b*), and (*c*) See Art. **69.**

(14) See Art. **103.**

(15) (*a*) and (*b*) See Art. **76.**

(16) See Art. **63.**

(17) See Art. **52.**

(18) See Art. **35.**

(19) (*a*) See Art. **68.**
(*b*) See Art. **69.**

(20) See Art. **45.**

INDEX

NOTE.—All items in this Index refer first to the section and then to the page of the section. Thus, *Alternator, §43, p31,* means that *Alternator* will be found on page 31 of section 43. When there are several items having the same key word, this is, for brevity, omitted after the first reference, and the other items are indented, or set in, from the left margin, to indicate this omission, which never consists of more than one word. Thus, under the key word *Brick* is found the indented item, *wall, Casement window in ;* this is read *Casement window in brick wall,* the capitalization of *Casement* denoting the first word of the reference.

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